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Quayside Operations Planning Under Uncertainty

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Sunday, 16:30-18:00

■ SA-03

Sunday, 16:30-18:00 - TIC Auditorium A, Level 2

Opening Session

Stream: Opening and Closing Session
Invited session
Chair: *David Pisinger*

1 - Opening Session
David Pisinger

Welcome to EURO2015. EURO is the premier European conference for Operational Research and Management Science. Our keynotes and plenary speakers are international thought leaders in their fields. Hear cutting edge ideas emerging from the Operational Research community.

Agenda: 1. Welcome addresses 2. Special Session to Commemorate Philippe Van Asbroeck 3. Awards 4. Plenary Presentation 5. Latest information & special remarks

Monday, 8:30-10:00

■ MA-01

Monday, 8:30-10:00 - Barony Great Hall

Tutorial Lecture: Thomas Stuetzle

Stream: Plenary, Keynote and Tutorial Sessions
Tutorial session

Chair: *Juan José Salazar González*

1 - Automatic Algorithm Configuration: Advances and Perspectives

Thomas Stützle

The design of optimisation algorithms for computationally hard problems is time-consuming and difficult. This is in large part due to a number of aggravating circumstances such as the NP-hardness of most of the problems to be solved, the difficulty of algorithm analysis due to stochasticity and heuristic biases, and the large number of degrees of freedom in defining and selecting algorithmic components and settings of numerical parameters. Even when using off-the-shelf software such as high performing IP solvers, their performance strongly depends on the appropriate settings of a large number of parameters that can influence their search behaviour. Over the recent years, automatic algorithm configuration methods have been developed to effectively search large parameter configuration spaces for identifying superior algorithm designs and performance improving parameter settings. These methods have by now proved to be instrumental for developing high-performance algorithms. In this talk, we will argue about the advantages of addressing algorithm design and configuration by algorithmic techniques; describe the main existing automatic algorithm configuration techniques; and discuss various successful applications of automatic algorithm configuration to configure mixed-integer programming solvers, the generation of hybrid stochastic local search algorithms, the design of multi-objective optimisers, and the improvement of algorithm anytime behaviour. Finally, we will argue that automatic algorithm configuration will transform the way optimisation algorithms are designed and developed in the future.

■ MA-02

Monday, 8:30-10:00 - Barony Bicentenary Hall

ROADEF/EURO OR Challenge presentation (I)

Stream: EURO Awards and Journals
Invited session

Chair: *Eric Bourreau*

1 - ROADEF OR Challenge presentation : Inventory Routing Problem at a glance with Air Liquide

Michele Quattrone, Jean André, Eric Bourreau, Marc Sevaux

The French OR Society (ROADEF) along with EURO, organizes periodically an OR challenge dedicated to industrial applications. This year, the challenge subject will be proposed by and industrial partner (AirLiquide) and will concern an Inventory Routing Problem. The challenge is open to everyone, and particularly to young researchers. The challenge problematic will be presented during this EURO 2015 and the results will be announced at EURO 2016 in Poznan. A prize of 20000 Euros will be awarded to the best teams. Contact: challenge@roadef.org

■ MA-03

Monday, 8:30-10:00 - TIC Auditorium A, Level 2

MAI: Speed networking

Stream: Making An Impact 1 (MAI 1)
Invited session

Chair: *Ramune Sabaniene*

1 - Speed networking: fruitful, fast and fun

Ramune Sabaniene

Networking as information exchange is not only essential to developing good professional practice, it is also an activity where we can all be givers. Generosity with one's own knowledge is the mark of a good professional.

EURO2015's 'Making an Impact' speed networking session gives a perfect opportunity to see how this works. It is designed so that even the shyest of us can join in without embarrassment. The outcome is an immediate boost to what you know about the world of OR practitioners, and to the number of people you may be able to turn to in the future — or who may be able to turn to you.

The session is designed so that you take part in a series of short focused meetings, introducing yourself to others and listening to what they have to say. You won't have time for long discussions — those can come later, over coffee or lunch — so make sure you are ready to spend a minute or so describing yourself and your interests. If you have business cards, bring them along to exchange; if you don't, we'll provide blank ones for you.

■ MA-04

Monday, 8:30-10:00 - TIC Auditorium B, Level 2

Retail Demand Planning

Stream: Demand and Supply in Retail and Consumer Goods
Invited session

Chair: *Winfried Steiner*

1 - Could Companies Gain from Fair Trade Labels? An Orange Juice Study

Friederike Paetz, Daniel Guhl

Socially conscious consumption, e.g., the consumption of fair trade products has increased enormously in the last decade. In contrast to conventional trade products, fair trade products adhere the guidelines (e.g., international labor standards or fairly compensation of workers) of fair trade-organizations. In spite of the increasing sales potential for fair trade products, most leading orange juice brands in Germany do not feature a fair trade label. Therefore, we investigate, whether German orange juice brands could gain from the admission of a fair trade label. Using a conjoint study, we estimate respondents' willingness-to-pay for fair trade labels. Furthermore, we determine respondents' "consciousness for fair consumption (CFC)' and examine interactions between respondents' level of CFC and price sensitivity. We found evidence, that generally the admission of a fair trade label increases respondents' utility for an orange juice. On average, the willingness-to-pay for fair trade labels is about 25 Eurocent, which implies a price premium of approximately 15%. Furthermore, increasing CFC-levels of respondents lead to decreasing price sensitivities as well as to increasing utility gains of the fair trade label. Hence, our results indicate that German orange juice brands may gain from the admission of a fair trade label as long as the additional costs do not excel the price premium.

2 - The Effect of Category Captains on Store Brands

Udatta Palekar, Erik Bushey

We consider the introduction of store brands when a retailer appoints a category captain (CC). Using a game theoretical model we consider the case of two national-brand manufacturers who are competing for the role of the category captain and the retailer requests one of the two to manufacture a store-branded product. We find that it is always beneficial for retailers to use a CC if they can control the marketing of the store brand made by the national-brand manufacturer. But the manufacturer may not be willing to make the store-brand product unless it is allowed to control its marketing and pricing. In that case, there are very few cases in which the retailer benefits from appointing a CC. In cases where the retailer does not benefit from store brand introduction and CC designation, we explore the possibility of getting a third-party to manufacture the store brand. We also investigate the role of the quality of the store-brand vis-a-vis the national brands.

3 - An Empirical Comparison of Demand Models in Food Retail

Stefan Minner, Anna-Lena Sachs

We test different demand models with customer number and transaction size distributions for a variety of food products and different stores. The comparison shows the advantage of a new compounded distribution compared to classical normal or negative binomial demand models and we further analyze the impact of serial demand correlation.

■ MA-05

Monday, 8:30-10:00 - TIC Auditorium C, Level 2

New Paradigms in Power Systems Planning

Stream: OR for Energy and Resource Efficiency
Invited session
Chair: *Valentin Bertsch*
Chair: *Tobias Lühn*

1 - Operational Strategies for Battery Storage Systems in Low-Voltage Grids to Limit the Feed-In Power of Solar Power Systems Using Fuzzy Control

Tobias Lühn, Jutta Geldermann

The energy turnaround of Germany leads to an increasing integration photovoltaics (PVs) throughout the German distribution grid. PVs are subject to large fluctuations in their power generation. Therefore, distribution system operators (DSOs) are faced with the challenge of preventing grid component overload as well as a violation of voltage range. A solution might be the integration of battery storage systems in private households and the active peak power reduction at the grid connection point. By using conventional operating strategies, peak shaving is often not possible and the PV-plant has to be throttled back. By optimizing the charge/discharge mode of solar energy storages with a fuzzy logic controller (FLC), the peak power generation from PV and the energy losses due to feed-in management can be reduced. In this study, the design and implementation of a FLC is developed. Input variables of the FLC are the solar surplus, the state of charge and the solar forecast of the following day. All input variables are standardized to ensure easy adjustments to different combinations of PV plant sizes and storage capacities. To obtain good results, the set of numerical parameters of the membership functions is enhanced by evolutionary programming. The simulations are carried out for the conventional battery operation as well as for the 'fuzzy' battery operation and point to a strong potential of the FLC to minimize the feed-in management.

2 - A Domain Decomposition Approach for Solving Optimal Economic Power Flow Problems in Parallel

Philipp Gerstner, Vincent Heuveline, Michael Schick

Against the background of liberalization of energy markets, increasing fuel costs and decentralized power generation by renewable energy sources, nowadays running an electrical power grid in an efficient way is becoming more important as well as getting more complex. The objective of an Optimal Economic Power Flow (OEPF) algorithm is to optimize the operation state of some given electrical network from an economic point of view, while maintaining technical restrictions in terms of limits on generators' real and reactive powers, node voltages, line flows etc. When employing any gradient based optimization algorithm such as Interior Point Method (IPM) or Sequential Quadratic Programming (SQP), the main computational effort lies in solving large and coupled linear systems. Even for medium-sized electrical networks, these systems can contain several millions of equations. The sparsity structure of the corresponding system matrix is closely related to the underlying physical model. In our work, we exploit this fact by using Schwarz preconditioning techniques in combination with iterative Krylov subspace methods such as GMRES for solving linear systems in parallel. In this talk, we address some issues when applying Schwarz methods to OEPF problems and present results concerning performance and parallel efficiency on suited benchmark problems.

3 - Dispatching Resolved Assessment of Technical and Operational Flexibility Upgrades with Improved Generator Model

Wolfgang Mohr, Eglantine Kunle, Martin Faulstich, Klaus Helbig

At high renewable energy share (>20%), even best dispatching methods will force conventional power plants to operate in excess to the flexibility they were originally designed for, causing poor efficiency, increased emissions, and high operational costs. Since a complete replacement of the plant is often too expensive and time consuming, affordable retrofits/upgrades are required to improve the stability of the grid. We propose a new method, which evaluates the economic benefit of products resulting in technical or operational changes for more flexible operation of conventional electricity generators by solving the self-scheduling profit maximization problem of an operator. The products are defined in detail, by specifying their effect on the transient processes, which are used to connect the states as function of internal parameters describing the generators state machine. The new method allows a simulation of power plants, with detailed calculation of state dependent transitions including optimised low load operation, maintenance cost, more accurate calculation of transient start-up costs and market details also integrating local fuel transport cost. The outcome of the optimization is in general more realistic than in case of standard dispatcher, which simplify the model for the sake of efficiency to a level, which prevents investigation of generator upgrades, required to develop a safe transition into a future with a dominant share of renewables.

4 - Optimal Load Shedding in Power Distribution Grids Based on Utility Functions for Demand Side Flexibility

Valentin Bertsch, Manuel Ruppert, Wolf Fichtner

Power generation in Europe continues to shift from centralised thermal power plants to decentralised, renewable energy sources. Among others, an expansion of smart grid technologies in distribution grids shall foster demand side flexibility and help to cope with the rising challenges of grid operation. Prospectively, the increasing diffusion of ICT will also lead to new possibilities in load shedding strategies. Most existing optimal load shedding approaches, however, are either based on a mere prioritisation or on cost functions. Our approach uses a utility function describing the loss in utility induced by a non-delivery of power for a certain consumer. For critical infrastructure elements connected to the power grid (e.g., health care facilities), the utility function incorporates information on their load profiles and coping capacities (e.g., auxiliary power units), an essential time-dependent component to be considered. For residential consumers, the utility function incorporates information on their load profiles and appliance utilisation preferences elicited within a nationally representative survey for Germany. Our approach is formulated as a nonlinear optimisation problem and solved by an interior-point method. We demonstrate our approach using a 33 bus reference grid. Our results reveal that the loss in utility can be minimised in comparison to traditional approaches by reallocating the non-delivery of power between critical infrastructure and residential nodes.

■ MA-06

Monday, 8:30-10:00 - TIC Lecture Theatre, Level 1

POM Assembly Lines I

Stream: Production and Operations Management
Invited session
Chair: *Sergey Kovalev*

1 - Profit maximization problem in two types of body shop assembly lines

Dug Hee Moon, Guan Wang, Yang Woo Shin, Jin Wook Kim

The function of body shop in automotive factory is to assemble various parts produced in press shop using welding processes. Generally, the body shop is divided into 15 20 sub-assembly lines. Each sub-line represents a welding area covering numerous welding operations in different stations. The decoupled sub-lines are connected with the electric monorail system (EMS). The function of EMS is the transportation of the sub-assembly to the next sub-line and also the preparation of buffer space preparing for any unexpected breakdowns of the two consecutive sub-lines. Each sub-line is a fully automated serial line with no buffer between operations and all operations in sub-line are synchronized. It means that although the real cycle times (welding times) are different among operations, the transportations to the next operation in a sub-line are occurred at the same time, and thus, this

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type of line is called as a transfer line. There are two types of construction methods in body shop, one is layered build method and the other is modular build method, and thus, the layouts is determined differently by the construction method. In this research, we compare two types of assembly layouts with respect to the profit maximizing when the objective function is composed with revenue caused by throughput, investment cost of EMS and robot, and cost of WIP. Overlapping decomposition method is used for estimating the throughput, and search method is used for optimizing the profit.

2 - A heuristic algorithm for two-sided assembly line rebalancing problem
Xiaofeng Hu

The continuous changes in product features and volume demand result in assembly line cycle time fluctuations. Consequently, the assembly tasks should be reassigned by considering the modification cost defined by the number of the task reassignments. Because of the shorter line length, reduced throughput time, and lower cost of tools and fixtures, two-sided assembly lines have been generally used for the large-sized products such as shovel loader, engine, trucks and buses. This paper proposes a heuristic algorithm for two-sided assembly line rebalancing problem (TALrBP) to minimize the cycle time and the number of task reassignments. Firstly, the specific differences of the rebalancing problem between one-sided and two-sided assembly lines are analyzed, and the directional workload gradient (DWG) along the assembly line is defined. Then, a heuristic algorithm based on the DWG and combined with tabu search procedure is proposed to solve the two-sided assembly line rebalancing problem. Finally, an example is used to show the procedure of the proposed algorithm, and the tests performed on some benchmark problems demonstrate its effectiveness.

■ MA-08
Monday, 8:30-10:00 - TIC Conference Room 2, Level 3

Planning Models in Industry

Stream: OR and Real Implementation
Invited session
Chair: *Ben Lev*
Chair: *Mohammad Dib*

1 - A predictive maintenance approach based on real-time process parameter monitoring
Chul Soon Park, Dug Hee Moon

This research proposes a predictive maintenance approach which is performed on injection molding machines of phone camera lens production lines. The proposed approach is based on the statistical process control technique with the real-time data monitoring of injection molding process parameters. First, components or equipment of injection molding machines, which are required for maintenance, are identified and then injection molding process parameters, which may be affected by mal-functioning of the previous identified components, are identified. Second, the process parameters, which significantly affect the quality of the lens and require a high degree of attention, are selected with regression analysis. Third, the statistical predictive models for the selected process parameters are developed to apply the statistical analysis techniques, which are used to evaluate their abnormal trends. Fourth, when the abnormal trends or patterns are found, the maintenance is notified with related components or equipment information. Finally, a prototype system is developed to show feasibility in Labview environment and an experiment is performed to validate our approach.

2 - Model predictive control type optimization technique for planning and scheduling
Hirokazu Kobayashi

In order to push smoothly forward the duties of the logistic process and production process in manufacturing industry, there must be production planning, production scheduling and transportation planning, in which appropriate quantity to produce and time of transportation are determined. However, in case that you directly formulate the production planning problem, production scheduling problem and transportation planning problem in mathematical programming, the scales of the formulated problems generally become enormous and you can't get the solution during the term in which you can endure practice use. In this study, I paid my attention to the fact that most of these problems in

manufacturing industry include a time element, and by introducing a thought of the model predictive control into the algorithm, I developed the technique to be able to get the overall solution. In the technique I divide the problem in a direction at time and solve repeatedly while letting time change forward. By this algorithm, I realized the technique by which I can draw up the plan and the schedule for a long term while balancing the calculation speed to get a solution and the quality of the solution which can endure practical use.

3 - A heuristic for the dispatch of interruptible resources
Mohammad Dib

Energy demand is rising sharply and the management of peak demand is becoming increasingly difficult. We should act on customer consumption. In our work, we try to do an intelligent management of interruptible resources by optimizing the way we reduce the consumption of customers. Our purpose is to find the best possible sequence of calls to interruptible resources. This optimization tries to maximize the benefit of the aggregator and to meet the production/demand balance. The calculation of the best possible sequence will be done by solving a maximization problem under constraints, which will vary according to one of two modes: Economic and dispatch. Our method is a heuristic one. It does not guarantee the obtaining of the best solution, but this method belongs to heuristic family and this latter is the only one that responds to the requirements of our client (obtaining of a good solution with less than 1 minute: import and export included). To validate our method, an aggregator gave us more than 1000 examples of possible real portfolios (50 to 1000 interruptible resources) with a combination of simple and coupling constraints. We then apply our approach. We compare our algorithm with an exact ILP. We implemented ILP using GAMS and we solved it with the Cplex solver with a MIP Gap of 0.0001. The results showed that our method gives solutions with 6% average gap to the solutions obtained by ILP. Its average speed is 80-times faster comparing to ILP.

■ MA-09
Monday, 8:30-10:00 - TIC Conference Room 3, Level 3

MAI: Group Causal Mapping: A visual approach to cognitive creativity

Stream: Making An Impact 2 (MAI 2)
Invited session
Chair: *L. Alberto Franco*
Chair: *Ashley Carreras*

1 - Group causal mapping: a visual approach to cognitive creativity
L. Alberto Franco, Ashley Carreras

A practically orientated session beginning with an outline of the types of circumstances for which group causal mapping has proven useful. The emphasis will be upon a live experience of a mapping session on an issue of relevance to all participants. You will get a first hand experience of developing a group map and thus a greater appreciation of how mapping can help in a variety of contexts.

■ MA-15
Monday, 8:30-10:00 - TIC Conference Room 6&7, Level 3

Cutting and Packing 1

Stream: Cutting and Packing
Invited session
Chair: *Julia Bennell*

1 - A MIP Model for the Irregular Strip Packing Problem
Luiz Henrique Cherri, Leandro Mundim, José Fernando Oliveira, Maria Antónia Carravilla, Franklina Toledo, Marina Andretta

A new mixed integer programming model to solve the irregular strip packing problem is proposed in this work. The irregular strip packing problem aims to place a set of pieces, that may be convex or non-convex and may have holes, in a strip with fixed height. The objective is to minimize the strip length used to pack all the pieces, ensuring that the pieces are all inside the strip and do not overlap. In the literature there are many heuristics proposed to solve the problem but only a few exact approaches. In the proposed MIP model, to avoid the overlap between the pieces, the nofit polygon is used in an innovative way. The model is robust in the sense that, for any piece shapes, no additional geometric structure is needed to represent the problem. The geometric structures needed to build the model are also easier to implement compared with the ones proposed in the literature. Computational experiments show that the proposed model proves optimality faster than the best model proposed in the literature.

2 - Nesting Post Processing: A Tool for Identification and Extraction of Usable Leftover Material

Felipe Ferrary, Jose Vicente Canto dos Santos, Raul Antonio Gerhardt

The following study aims to implement a feature capable of recognizing and saving the scrap area from raw material sheets submitted to a nesting process in order to fill this sheet with given parts followed by a CNC cutting process. In this study, the material portion which is not used after the cutting process is identified and defined as scrap. In order to be easily implemented in CAD/CAM software, two different methods to extract a 2D profile which represents the scrap area are proposed. One method involves a low processing level, but outputs approximate results. This first method will enclose all parts in a rectangular area and uses its edges to define the part limits. The other method involves a high processing level, however it outputs truthful results considering the real part profiles as well as diameter of the cutting tools used during the process. Once the scrap profile is extracted, an evaluation of this scrap is made in order to define if the profile is a usable leftover or not. Usable leftovers are automatically stored in a database and non-usable ones are discarded. Through this database, it is possible to reuse the extracted scrap sheets as well as improve the management of the sheets in the inventory. Once one of the sheets from the inventory fits the requirements of a new project, it is possible for the CAM programmer to select and reuse it. During the tests, both methods have shown satisfactory results near of the real scrap.

3 - A Semi-continuous Model for the Irregular Strip Packing Problem

Aline Leão, Franklina Toledo, José Fernando Oliveira, Maria Antónia Carravilla

In the irregular strip packing problem, we are given a set of two-dimensional irregular pieces to be packed in one board with a fixed width and an infinite length. The objective is to pack all pieces while minimising the used board length. In the literature, there are only few mathematical models for the problem that can be classified into discrete and continuous positioning models for the pieces on the board. We developed a semi-continuous positioning model by considering a semi-discrete positioning for the pieces. Computational results show that the model is competitive with the models in the literature and takes some advantages of both configurations.

4 - Exact MIP Based Algorithms to Solve the Irregular Strip Packing Problem

Julia Bennell, Antonio Martinez Sykora, Ramon Alvarez-Valdes

In this work we present two new mixed integer linear programming formulations for the two-Dimensional strip packing problem with irregular shapes, also known as nesting problems. For many benchmark data sets, the pieces are allowed to be rotated by a finite set of angles. In these problems there are two families of inequalities, the containment inequalities and the non-overlapping inequalities. It is well known that the non-overlapping inequalities considerably increase the difficulty of solving these models. Therefore, we explore two alternative ways to formulate the non-overlapping constraints that permit a given set of orientations of the pieces. The first model uses the nofit polygons to write the non-overlapping inequalities and introduce binary variables to select the orientation used by the pieces. In the second model we introduce a new use of the nofit polygon in which different nofit polygons are combined, leading to more promising models. We prove the efficiency of both models in a set of small instances, proving optimality in instances up to 12 pieces with 4 angles of rotations.

■ MA-16

Monday, 8:30-10:00 - TIC Conference Room 8, Level 3

Sustainable Food Supply Chains

Stream: Sustainable Supply Chains
Invited session
Chair: *Jacqueline Bloemhof*

1 - Integrated Process and Network Optimisation for Sustainable Food Supply Chains

Jochem Jonkman, Jacqueline Bloemhof, Jack van der Vorst, Albert van der Padt

A Food Supply Chain has to deal with the specific requirements of food products, related to product characteristics such as shelf life and quality. These characteristics are partially determined or influenced by the activity of food processing. Therefore, the food supply chain design is related to the activities at the processing level. What may seem as the best design at the processing level may lead to a sub-optimal supply chain and vice versa. However, in food process design, the supply chain is often left out of scope, or considered as a black box. Likewise, in (food) supply chain design the process step is often approached as a black box. We show that combining food supply chain design and food process design leads to an increased understanding of the intertwined design problem. Mathematical modelling is used to obtain quantitative data for decision support. Knowledge from the fields of Process Systems Engineering and (Food) Supply Chain Management is combined into an innovative method to provide decision support for the food process and supply chain design problem. In particular, attention is given to the specific characteristics of food production chains like region-specific availability of raw materials, seasonality and quality of the products throughout the chain. A MILP model is presented for the integrated multi-objective optimisation of a food process and supply chain design, taking into account performance indicators from different sustainability domains.

2 - Water Footprint and Sustainable Agrifood Supply Chains: a System Dynamics Methodology

Naoum Tsolakis, Eirini Aivazidou, Dimitrios Vlachos, Eleftherios Iakovou

Rising water scarcity (WS) has emerged as an indisputable threat for both society and corporations, leading to multiple environmental, social and economic ramifications. In particular, freshwater is a pivotal constituent in the agrifood industry since the agricultural activities consume 70% of the global freshwater resources. In this context, the scientific community has introduced the water footprint (WF) concept for evaluating freshwater consumption and pollution across food supply chains at a national, corporate or even product level. WF may be closely related to (environmental and social) sustainability, since WF within a catchment area should remain within certain limits. This study proposes a policy-making methodology based on System Dynamics (SD) for controlling WF of agricultural production and food processing operations within a specific geographical area. More specifically, the developed SD model assists in: (i) monitoring the WF and WS of the system under study for a long-term horizon, and (ii) evaluating the impact of alternative interventions concerning WF management for the region in terms of economic, environmental and social sustainability. The applicability of the proposed methodology is illustrated through its implementation in a specific region in Greece. Finally, the research provides managerial insights with respect to policy-making interventions towards the sustainable development of agrifood supply chains and the agrifood sector.

3 - Ensuring Economically Feasible Biogas Projects by Optimisation of the Value Chain

Ida Græsted Jensen, Nina Juul

Focus on sustainable energy increases along with the interests in alternative fuels like biogas. However, making the production of biogas economically beneficial is still a challenge. In Denmark, a governmental goal for 2020 is that 50% of all manure must be used in biogas production. This increases the interest for a decision support tool to ensure that the biogas projects become economically feasible.

We consider the chain of production, from the farmer, or another primary source, through transportation, pre-treatment etc. to end-use in terms of electricity, heat, transportation fuel, or input to the natural gas grid. The cost of each part of the chain is evaluated to ensure that the problem becomes feasible for all partners in the project. For this purpose, we have developed a flow model with the objective to reduce the

cost of the chain as well as to ensure benefits at each stage of the model as far as possible.

We have focused on the case of Denmark. Results show that the value of the resources used for biogas production has large impact on the profitability of the project. Furthermore, we have found that optimal use of biogas for small-medium plants is generation of combined heat and power. In terms of modelling, we find that assumptions regarding investment costs and value of the heat and power output has a high impact on optimal production as well as the profitability of the project.

4 - A Hybrid Two Staged Approach for the Design of Sustainable Agri-Food Supply Chain Networks
Alok Choudhary, Hamid Allaoui

Design of agri-food supply chain is confronted with increased consumer demands on food quality and increased focus on sustainability. The main contribution of this research is twofold: First, it introduces a systematic literature review on Operational Research tools and methods for the design of sustainable supply chain. Second, it presents a hybrid approach to design the sustainable agri-food supply chain. The triple bottom line of sustainability has been taken into consideration in this approach. It allows putting forward two distinct phases (1) In phase one of the decision making process, a multi-criteria decision making model is utilized, based on an aggregation model using an extension of the AHP process followed by the OWA operators. This phase has its practical meaning in aggregating supply chain performance and assessing the supply chain partners. The very nature of the AHP and OWA procedures gives rise to their combination and creates a more powerful decision making tool. (2) In phase two, a mathematical model with multi-objective function is proposed to optimize the design of the agri-food supply chain network and identify the optimal routing decisions. An efficient method to generate the pareto front of the mathematical model is presented and comparative analysis shows the efficiency and effectiveness of the proposed approach.

■ MA-17

Monday, 8:30-10:00 - TIC Conference Room A, Level 9

Game Solutions and Structures

Stream: Game Theory, Solutions and Structures
Invited session
Chair: *Encarnación Algaba*

1 - Efficient Extensions of the Myerson Value
Frank Huettner, Sylvain Béal, André Casajus

We study values for transferable utility games enriched by a communication graph (CO-games) where the graph does not necessarily affect the productivity but can influence the way the players distribute the worth generated by the grand coalition. Thus, we can envisage values that are efficient instead of values that are component efficient. For CO-games with connected graphs, efficiency and component efficiency coincide. In particular, the Myerson value, Myerson (1977) is efficient for such games. Moreover, fairness is characteristic of the Myerson value. We identify the value that is efficient for all CO-games, coincides with the Myerson value for CO-games with connected graphs, and satisfies fairness.

2 - Potential, Voting and Power
André Casajus

We advocate a new index of absolute power for simple superadditive games (voting games). In particular, we suggest that overall power should equal the game's potential due to Hart and Mas-Colell (1989, Econometrica 57, 589-614), who feel that "the potential provides the most natural one-number summary of a game.' This index exhibits appealing properties with respect to overall power assigned in a voting game, which are not met by the Penrose-Banzhaf index, for example. (i) Overall power for unanimity games strictly decreases with the number of players needed to win the vote. In particular, it equals the reciprocal of this number. (ii) Overall power is greatest only if the game contains a dictator. Overall power is lowest only if all players are needed to win the vote. This index also shows a number of appealing monotonicity properties with respect to individual power. (i) Strong monotonicity: A coalition is swing for some player if it is losing, but becomes winning when this player enters the coalition. Strong monotonicity: Whenever the swing set of some player in one game is

contained in her swing set of another game, then this player's power in the latter game is not lower than in the former. (ii) Desirability: Whenever the set of swings for a particular player not containing the second one is contained in set of swings of another player not containing the first one, then the latter player's power is not lower than the former player's.

3 - Characterization of the Average Tree Solution and its Kernel
Philippe Solal

In this article, we study cooperative games with limited cooperation possibilities, represented by a tree on the set of agents. Agents in the game can cooperate if they are connected in the tree. We first derive direct-sum decompositions of the space of TU-games on a fixed tree, and two new basis for these spaces of TU-games. We then focus our attention on the Average (rooted)-Tree solution (see Herings, P., van der Laan, G., Talman, D., 2008. The Average Tree Solution for Cycle-free Games. Games and Economic Behavior 62, 77-92). We provide a basis for its kernel and a new axiomatic characterization by using the classical axiom for inessential games, and two new axioms of invariance, namely Invariance with respect to irrelevant coalitions and Weighted addition invariance on bi-partitions.

4 - Values for Games under Precedence Constraints
Encarnación Algaba, Rene van den Brink, Chris Dietz

In this paper we deal with games under precedence constraints introduced by Faigle and Kern (1992) who also introduce a generalization of the Shapley value for such games. They characterized this solution by efficiency, linearity, the null player property and an axiom called hierarchical strength which states that in a unanimity game the payoffs are allocated among the players in the unanimity coalition proportional to their hierarchical strength in the corresponding coalition. We introduce a new solution for games under precedence constraints, so-called hierarchical solution. Unlike the precedence Shapley value, this new solution satisfies the desirable axiom of irrelevant player independence which establishes that the payoffs assigned to relevant players are not affected by the presence of irrelevant players. This solution is defined in a similar spirit as the precedence Shapley value but belongs to the class of precedence power solutions being solutions that allocate the dividend of a coalition proportionally to a power measure for acyclic digraphs. The hierarchical solution allocates proportionally to the hierarchical measure which is axiomatized on the class of acyclic digraphs.

■ MA-18

Monday, 8:30-10:00 - TIC Conference Room B, Level 9

Software for Optimization Modeling 1

Stream: Software for Optimization
Invited session
Chair: *Robert Fourer*

1 - A review on some GAMS features used in real world optimization projects
Toni Lastusilta

From the beginning in the 1970s at the World Bank till today, GAMS, the General Algebraic Modeling System, has evolved continuously in response to user requirements, changes in computing environments and advances in the theory and practice of mathematical programing. In this presentation we will outline several real world optimization projects, where GAMS was chosen as the optimization tool. We will highlight some of the key features in GAMS that have been used to carry out these projects.

2 - Building AMPL Models Into Applications
Robert Fourer

Algebraic modeling languages were developed with the goal of making optimization models much easier to develop, debug, and maintain. However it is not necessary to give up these advantages when embedding a model into a larger system or deploying it to users. Two distinct facilities of modeling languages are commonly used to integrate models into applications. Scripting brings the programmer to the modeling language, extending the language so that the same constructs convenient for describing a model can also be used to specify how the model

will be used in a broader context. APIs bring the modeling language to the programmer, providing access to model objects and methods for applications written in general-purpose programming languages. The strengths of these two approaches are contrasted by comparing implementations of column-generation schemes for cutting problems.

3 - Network Optimization using AIMMS in the Analytics & Visualization Era
Ovidiu Listes

We share modeling and visualization aspects for network optimization using AIMMS, as well as several use cases for network planning applications. We touch on network model building and show how to deal with complexity and uncertainty in AIMMS-based network optimization models. We also discuss how to move from a model to an application, including deployment in a client - server architecture and visualization using both Windows-based and Web-based user interfaces.

4 - Introducing new release 5.0 of the MPL Modeling System and the OptiMax Component Library
Bjarni Kristjansson

To be entered

■ MA-24
Monday, 8:30-10:00 - John Anderson JA3.25 Lecture Theatre

MADM Application I

Stream: MADM Applications
Invited session
Chair: *Chie-bein Chen*

1 - Investment Decision-analysis for Public Art Exhibition
Wen-Tsung Wu, Chie-bein Chen, Shih-Yu Yang, Vivien Y.C. Chen

This research focuses on strategy planning exhibitions to implement the public art work — The Rubber Duck - designed by Florentijn Hofman. This research focuses on the Chinese agencies and organizers of Hofman who conducts the "Rubber Duck' exhibition in the city of Hangzhou Xixi-wetland National Park in China and investigates whether random public art indicators influence the estimated effects before exhibition and actual benefits after exhibition or not? This research evaluates the profits and the input investments by Net Present Value (NPV), internal rate of return (IRR) and Game Options methods. According to the analysis of mathematical models, these models can provide various analysis results in different time periods for the decision makers and help them to decide whether to invest the exhibition in those cities or not? In the meantime, these analysis results can help organizers to decide whether the suitable decision to excuse exhibition in that cities or not?

2 - Evolutionary Algorithms for Multi-player Games to Optimize the Profit of Cooperative Advertising in Supply Chain
Chie-bein Chen, Wen-Tsung Wu, Jung-Ho Lu

The primary objective of this research is intended to construct the mathematic game models with different market response functions of cooperative advertising and applies the evolutionary algorithms to identify the game equilibrium (or solutions) in supply chain. The manufacturers whose polices in the long-term branding investments might influence the retailers' polices in the short-term promotion efforts. The research problems is to solve the cooperative advertising game problem under different market response functions using swarm particle optimization-crowding distance (MOPSO-CD) or non-dominated sorting genetic algorithm (NSGA II) to identify the multiple manufacturers and retailers (M-Rs) Stackelberg games' equilibriums. In the Stackelberg game, it is not only each manufacturer or each retailer could be randomly the leader or follower, but also all manufacturers are fixed together or all retailers are fixed together as a leader in the game situation. Finally, this research will implement a simulated case and their numerical results will demonstrate the feasibility.

3 - Dynamic Process of Economic Integration between China and the ASEAN-5: Evidence from Recursive Cointegration Analysis
Chang Lee Shu-Jung, Mei-Se Chien, Lee Chien-Chiang, Wu Yi-Hsuan

Several regional initiatives have reinforced financial cooperation and integration in Asia. The speed and depth of growth and economic integration in East Asia has been amazing. This paper examines the dynamic process of real and monetary integration, including growth rate of base money, growth rate of M2, the CPI and industrial output index, between China and the ASEAN-5 countries. Considering the importance of time variation in these economic linkages, recursive cointegration is used in this paper to examine the dynamic evolution of real and monetary integration in these countries. The empirical results of the Gregory and Hansen(GH) cointegration test confirm there is no cointegration between China's CPI and ASEAN-5's CPI. As to other variables, no matter growth rate of base money, or growth rate of M2 or industrial output index, the empirical results of the GH show that there is a cointegration between China and ASEAN-5. The empirical results of the recursive cointegration analysis of CPI confirm existing of cointegration between China and ASEAN-5 after 2009. Besides, the empirical results of growth rate of base money and M2, shows that, there is a cointegration between China and ASEAN-5. Finally, the industrial output index between China and ASEAN-5 countries are cointegration after 2007, which implies real active integration is existing among China and ASEAN-f in the long run.

4 - Evaluating travel risks from tour guides' perspectives: Analytic Network Process Application
Chin-Tsai Lin, Shih-Chieh Hsu, Juo-Yi Sun, Yi-Shan Chen

The economic prosperity, tourism industry is growing and developing in the Asia Pacific region. This study explores the travel risks in Taiwan from tour guides' perspective for its evaluation. In this research, modified Delphi method is used to identify the evaluation criteria. Further analytic network process (ANP) is applied to determine the relative weights of various travel risks evaluation criteria. Analytic network process (ANP) is not only an appropriate tool for multicriteria decision-making (MCDM) but can also be applied in academic research to prioritize factors or criteria and to emphasize the interdependent relationships, thus increasing the accuracy of our results. It further consideration the travel risks evaluation results can be used for tourism industry to review, improve, and enhance tour planning and risk management in the future.

5 - Development optimal site selection factors of Hostels
Pin-Ju Juan, Peng-Yu Juan

The purpose of this study is to develop indicators to measure the hostels optimal site selection with a sustainable framework. In order to develop such objective indicators, this study employed a modified Delphi technique. A panel of 24 academic researchers in tourism provided input into developing the indicators. After three rounds of discussion, the panel members reached consensus on the set of indicators. Passing the result of studies, this research will construct a evaluating pattern of the optimal site selection established hostels of the competitive advantage to take it as evaluating the standard operational procedure (sop) of the optimal site selection that hostels are established.

■ MA-25
Monday, 8:30-10:00 - John Anderson JA3.14 Lecture Theatre

Uncertainty in Multicriteria Optimization

Stream: Continuous Multiobjective Optimization and Robustness
Invited session
Chair: *Andrea Raith*
Chair: *Marie Schmidt*

1 - Competitive Analysis for Multi-Objective Online Algorithms
Morten Tiedemann

So far, the concept of competitive analysis for online problems is in general applied to single-objective online problems. However, many online problems can be extended to multi-objective online problems in a natural way, but a uniform theory for the analysis of these problems is not provided in the literature. We expand the concept of competitive analysis to multi-objective online problems and achieve a consistent framework for the analysis of multi-objective online problems. Furthermore, we analyze the multi-objective time series search problem and present deterministic algorithms with best possible competitive ratios.

2 - Regularization Robustness in Multi-Objective Optimization

Corinna Krüger, Anita Schöbel, Gabriele Eichfelder

In many real-world applications of mathematical optimization uncertainties in decision variables have to be taken into account. For instance in agricultural industry, a calculated amount of peat, which is used to raise plants, can not be realized exactly but only within some accuracy. In single-objective optimization uncertainty in decision variables is treated in the research area "Regularization Robustness", see e.g. Lewis, 2002.

In this talk, we present an extension of the framework of single-objective regularization robustness to multi-objective optimization. For each solution, we consider the set of all of its possible realizations instead of the solution itself. Therefore, we have to compare sets instead of points in order to find non-dominated solutions.

We show that our concept is identical to the classical single-objective definition of regularization robustness, whenever it is applied to a single-objective problem. Furthermore, our formulation of multi-objective regularization robustness fits into the framework for multi-objective optimization with parameter uncertainties of Ehrgott et al, 2014. We show first theoretical results for the new concept. Amongst other issues, we investigate variable uncertainty in multi-objective optimization with linear objective functions and objective functions where each component is [./strictly/strongly] de- or increasing.

■ MA-26

Monday, 8:30-10:00 - John Anderson JA3.17 Lecture Theatre

Combinatorial Problems in Production/Inventory/Logistics systems 1

Stream: Scheduling with Resource Constraints
Invited session
Chair: *Sergey Kovalev*
Chair: *Roberto Rossi*

1 - Time-expanded Linear Programming Models for Multi-objective Multimodal Trip Planning Problem

Sergey Kovalev

We study a multi-objective multi-modal trip planning problem. In a context of online trip planning, a traveler is supposed to choose and rank a set of trip-related criteria, enabling a lexicographic order. A planner, equiped with supercomputing resources, applies a Boolean Linear Programming (BLP) model to each problem related to a certain criterion. Problems are solved sequentially according to the lexicographic order. BLP models are time-expanded, which means that each node in a multimodal network keeps the information about a geographical point and the discrete time of a departure or arrival event. The proposed solution method was tested on a real urban transport network with 22143 nodes and about 360000 arcs. The obtained results are promising and pave the way for using this method in operational conditions.

2 - A Mixed Integer Linear Programming Heuristic for Computing Nonstationary (s,S) Policy Parameters

Roberto Rossi, Onur A. Kilic, Armagan Tarim

The stochastic lot-sizing problem consists in controlling an inventory system facing random demand over a given planning horizon. The decision maker faces inventory holding costs, if she orders too much; and backorder penalty costs, if she orders too little and demand fulfillment is delayed until the next replenishment arrives. Each time production runs there are fixed and variable production/ordering costs that must

be accounted for while controlling the system. The structure of the optimal control policy to this problem has been characterised over fifty years ago by Scarf. This control policy, named (s,S) monitors the inventory position, i.e. on hand stock minus backorders plus incoming orders, and issues an order to bring the inventory position up to S whenever the inventory position falls below s. In this work we develop an MILP based heuristic for computing nonstationary (s,S) policy parameters. The key insight upon which our approach is based comes from a recent study showing that a nonstationary (R,S) policy often performs very close to optimal. The idea is then to use an existing MILP model for computing nonstationary (R,S) policy parameters as a proxy to determine near optimal (s,S) policy parameters. Our heuristic is easy to implement, since it is based solely on a standard MILP model and on a simple binary search procedure. It performs better than other existing approaches, featuring an average optimality gap of 0.2% on our preliminary tests.

3 - A Robust Approach for Vessel Crew Scheduling Problem

Seda Sucu, Kerem Akartunali, Robert Van der Meer, Alexander Leggate

Due to crew costs being a significant proportion of operational costs and sophisticated requirements for crew members' assignments on a global scale, crew scheduling problems have gained much more importance in the area of scheduling in recent years. However, the literature on crew scheduling covers almost exclusively airline transportation settings whereas there is very limited research in the maritime industry, where sudden changes, uncertainties and the cost resulting from such changes are relatively high. In our study, we have been working on the allocation of crew members to the vessels under uncertainty. In terms of the complexity of rules and regulations, vessel crew scheduling problems have some similarities and some differences with airlines, which need to be taken into account for the optimal assignments. These problems generally have many binary variables even in the deterministic model, and combined with long duty periods and planning horizons, long solution times are common for these problems. We suggest the possible sources of uncertain situations in vessels and discuss robust approaches to deal with the uncertainties of constraints in the scheduling model.

4 - Batch Processing of Identical Jobs with Cubic Incompatibility Graphs on Three Uniform Machines

Marek Kubale

A batch processing machine is one that can process several jobs simultaneously. In the talk we consider the problem of scheduling n identical jobs on 3 uniform s-batch machines with different speeds to minimize schedule length. We assume that the jobs are restricted by mutual exclusion constraints modeled by a cubic incompatibility graph G. In other words, we assume that each job is in conflict with exactly three other jobs, e.g. because they need the same shared resource. Therefore the problem reduces to an appropriate decomposition of G into 3 independent sets (batches). We show that if G is 2-chromatic then the problem can be solved in $O(n2)$ time. If the incompatibility graph is 3-chromatic, the problem becomes NP-hard even if two machines run at the same speed. However, in this case there exists an approximation $O(n3)$-time algorithm with performance ratio less than 4/3. Moreover, this algorithm solves the problem almost surely to optimality if the fastest machine performs only slightly faster than the remaining two. If G is 4-chromatic then clearly there is no solution to our scheduling problem.

■ MA-27

Monday, 8:30-10:00 - John Anderson JA3.27, Level 3

Stochastic Programming and Applications

Stream: Stochastic Optimization
Invited session
Chair: *Janny Leung*

1 - A Tri-level Programming Model for Disaster Relief Planning based on a dual-ascent solution approach

Janny Leung, Takashi Irohara, Yong Hong Kuo

The past decade has witnessed major natural and man-made disasters all around the world. Practitioners have recognised that strategic location of depots and pre-positioning of inventory greatly facilitate the speed and efficiency of evacuation and/or delivering supplies in the crucial days immediately after disaster strikes. This paper proposes a tri-level programming model for disaster preparedness planning. The top level addresses facility location and inventory pre-positioning decisions; the second level represents damage caused by the disaster, while the third level determines response and recovery decisions. We use an interdiction framework instead of a stochastic or chance-constrained model. This allows the extent of damage to be treated as a parameter to facilitate scenario exploration for decision-support. We develop an iterative dual-ascent solution approach. Computational results show that our approach is efficient. We also draw insights from the computational instances for helping disaster relief planning.

2 - Solution of two-stage stochastic scheduling problems by stage decomposition and ordinal optimization

Thomas Siwczyk, Sebastian Engell

Scheduling problems with uncertainty can be modeled by two-stage stochastic MILP (2SSP), where the future evolution is modeled by a discrete set of scenarios. With an increasing number of scenarios the resulting MILP problems become very hard to solve in a monolithic fashion. To find good solutions in reasonable computation times, in our previous work stage decomposition was successfully applied to solve 2SSP. The first stage problem is solved by an evolutionary algorithm, while the second-stage subproblems are solved exactly by a MILP-solver. So for each tested solution for the first-stage variables, all scenario subproblems have been solved to optimality. We present a new idea for solving large-scale 2SSP under uncertainty based on stage decomposition and the principles of Ordinal Optimization (OO). According to OO it is easier to create a ranking of multiple solutions than evaluating their exact values. Hence an inexact evaluation can be used to determine a ranking of solutions (with a small error), allowing us to find good solutions for large problems in relatively short computation times. We evaluate our approach by a case study of a chemical batch plant. Different evaluation methods for the ranking of the solutions are compared to the true ranking provided by an exact evaluation to validate the claim that an inexact evaluation can be used in the optimization of the first-stage solutions. The algorithm is tested experimentally and compared to standard solution methods.

3 - Problem-driven scenario generation for stochastic programs with tail-risk measure

Jamie Fairbrother, Stein W. Wallace

Stochastic programming is a tool for making decisions in the presence of uncertainty which allows users to explicitly model future decisions and costs based on investment decisions and realisations of a priori unknown parameters. However, the flexibility of stochastic programs comes at a price: they tend to only be tractable for problems where uncertain parameters are modelled by a finite number of possible future scenarios. How we generate these scenarios plays a key role on the quality of the solution a stochastic program yields.

The mean-risk approach in stochastic programming is to choose a decision which somehow balances expected profit against the risk of some investment. Tail risk measures (such as VaR and CVaR) are an important class of risk measures as they give one an idea of how much capital should be held to cover the most extreme losses. However, these are problematic as they typically only depend on a fraction of the scenarios we generate for a problem. This means that a scenario generation method will usually yield an unstable solution solution unless we use a large and computationally expensive number of scenarios.

In this work we argue that we can gain better solutions with fewer scenarios by concentrating the scenarios in an area which we call the risk region. We characterise this region exactly for a class of portfolio selection problems, and demonstrate numerically the improvements of our methodology over standard scenario generation methods.

■ MA-28

Monday, 8:30-10:00 - John Anderson JA3.26, Level 3

On Some Game Theoretical Problems

Stream: Allocation Problems in Game Theory and Some Problems on Inventory and Logistics Situations
Invited session
Chair: *Marco Slikker*

1 - A Game Theoretic Approach for the Allocation of Greenhouse Gas Emissions in Supply Chains

Daniel Granot, Frieda Granot

Globalization, which exports production and jobs from rich countries to poor countries, also exports from rich countries to poor countries the greenhouse gas (GHG) emissions created from the production of the goods consumed by rich countries. But whose responsibility are the GHG emissions? Are they exclusively the responsibility of the producing countries, or exclusively the responsibility of the consuming countries? Or, perhaps, the responsibility for the GHG emissions should be shared by both the producers and the consumers?

Our approach to the GHG emission responsibility (GGER) problem is to formulate it as a cooperative game, referred to as the GGER game, and use cooperative game theory methodology to suggest allocations of GHG responsibility among the various parties in the supply chain. We prove that the GGER game is convex, and thus has a non-empty core, and we identify some allocation methods which are extreme core points and are used in practice. We derive an explicit expression for the Shapley value of the GGER game, which is shown to have a very simple and intuitive interpretation, and we further develop an efficient algorithm to compute the nucleolus in some instances of the GGER game. We illustrate our approach by allocating GHG emissions in a newspaper publishing supply chain.

This talk reports on joint work with Greys Sosic and Hailong Cui, Marshall School of Business, USC, and with Sanjith Gopalakrishnan, Sauder School of Business, UBC.

2 - Cooperation and Contract Design in Project Management with Outsourcing

Xiao-qiang Cai, Nicholas Hall

We study a project management problem in which the prime contractor outsources tasks to a set of subcontractors. Achieving an optimal project schedule requires: (i) coordination among the subcontractors; and (ii) contract design by the prime contractor, to incentivize the subcontractors. We model the coordination problem of the subcontractors as a cooperative game. We show that this game is balanced, hence the subcontractors cooperate if an appropriate profit sharing scheme is adopted. We derive such a scheme by solving a linear program. We consider the contract design problem of the prime contractor in two cases: a uniform contract across all the subcontractors, and a nonuniform one that customizes incentives for each subcontractor. We develop efficient algorithms to compute the optimal contract parameters in both cases. We conduct computational experiments to analyze the sensitivity of project performance to parameter estimation in contract design. We find that the pooling effect of subcontractors' cooperation mitigates the negative impact of poor estimates. We also observe three unexpected results: (i) the subcontractors' profits may decrease if they provide false information; (ii) it is safer for the prime contractor to overestimate subcontractors' crashing costs than to underestimate them; and (iii) uniform contracts often deliver more project profit, although the prime contractor's profit share is always larger under nonuniform contracts.

3 - Spare Parts Pooling under Criticality Differences

Loe Schlicher, Marco Slikker, Geert-Jan van Houtum

We consider an environment wherein several service providers with possibly criticality differences can collaborate by pooling their spare parts. Every collaborating group of service providers uses a critical level policy that focusses on the long-term average cost. We examine the allocation of the collective cost savings for such pooled situation by studying an associated cooperative game, which we call a criticality game. We analyze various properties of these criticality games.

4 - Cost Allocation Rules for Elastic Single-Attribute Situations

Marco Slikker, Frank Karsten, Peter Borm

Many cooperative games, especially ones stemming from resource pooling in queueing or inventory systems, are based on situations in which each player is associated with a single attribute (a real number representing, say, a demand) and in which the cost to optimally serve any sum of attributes is described by an elastic function (which means that the per-demand cost is non-increasing in the total demand served). For this class of situations, we introduce and analyze several cost allocation rules: the proportional rule, the serial cost sharing rule, the benefit-proportional rule, and various Shapley-esque rules. We study their appeal with regard to fairness criteria such as coalitional rationality, benefit ordering, and relaxations thereof. After showing the impossibility of combining coalitional rationality and benefit ordering, we show for each of the cost allocation rules which fairness criteria it satisfies.

■ MA-29

Monday, 8:30-10:00 - John Anderson JA4.12, Level 4

Data Analysis for Emerging Applications 1

Stream: Data Analysis for Emerging Applications
Invited session
Chair: *Ozden Gur Ali*

1 - Aggregation of density forecasting algorithms
Alexey Romanenko

This contribution deals with applying the strong aggregating algorithm to time series density forecasting problem. A particular example is the problem of time series forecasting where we need to estimate a probability distribution of possible future values of a sequence. In this case the loss function compares the actual value of the time series with predicted density distribution at each trial. We use modifications of some adaptive time series methods including exponential smoothing, linear model of Brown, and Theil-Wage model for building base algorithms. The aggregating algorithm is considered as a method for building compositions of base algorithms. We specify sufficient conditions under which a composition based on the aggregating algorithm performs as well as the best of base algorithms. As a result, we find a theoretical bound for the loss process of a given composition. On the practical side, we have carried out several experiments with real sales data of retail nets. We show that the theoretical bound of the compositions is in agreement with practical results and can be relied on. Finally, we obtain that the compositions based on the aggregating algorithm outperform both base algorithms and other well-known density forecasting algorithms in practice.

2 - Important Degree Analysis of Motives in the Seven Steps purchasing Behavior Process by AHP
Xueyin Chen, Kanyakorn Rungrassamee, Xun Zhang, Hong Seung Ko

Most of companies around the world try to improve their profitable sales by retaining customers. However, there are few marketing strategies for retaining customer. Especially, it is very difficult to retain a customer in online business environment. It is necessary to find out a suitable marketing strategy for getting sales and profits by retaining customers in online. To set up a suitable marketing strategy for retaining a customer in online, an e-customer purchasing behavior process is needed We consider the seven steps of an e-customer behavior process proposed by Ko et al as a proper model for retaining a customer in online business environment. Therefore, we must check the important degree of six motives up in this behavior process. It is because those six motives are very valuable factors in this behavior process for retaining a customer on online. Consequently, we analyze the important degree of those six motives by AHP.

3 - Multi-Period Ahead Prediction with Residual Extrapolation and Information Sharing
Ozden Gur Ali

Multi-period sales forecasts are important inputs to operations at retail chains with hundreds of stores, many formats, customer segments and categories. Beyond seasonality, holidays and marketing, correlated random disturbances affect sales across stores that share common characteristics. We propose a novel method, 2 Stage Information Sharing, that leverages this challenging complexity: Segment-specific panel regressions with seasonality and marketing variables pool the data for better parameter estimates. The residuals are extrapolated non-parametrically using features that are constructed from the last twelve months of observations from the focal and related category-store time series. The final forecast combines the extrapolated residuals with the first stage forecasts. Working with the extensive dataset of the leading Turkish retailer, we show that the method significantly outperforms panel regression models (mixed model) with AR (1) error structure and the Autoregressive Distributed Lags (ADL) model as well as the univariate exponential smoothing (Winter's) forecasts. The farther out the prediction, the more the improvement.

■ MA-30

Monday, 8:30-10:00 - John Anderson JA5.02, Level 5

Robust Routing and Scheduling

Stream: Robust Optimization
Contributed session
Chair: *Chungmok Lee*

1 - Generating Robust Schedules for Parallel Machines in the Face of Processing Time Variability and Machine Breakdowns
Selçuk Gören, Rahime Şeyma Bekli

Even though classical scheduling theory usually neglects the dynamic and stochastic nature of production environments encountered in practice, most environments are subject to unexpected disruptions such as machine breakdowns, processing time variability, order cancellations, and so on, that prevents production schedules to be implemented exactly as they are generated. During past two decades, scheduling in the face of uncertainty has gained much research interest to bridge this gap between scheduling theory and practice.

In this study, we consider a production environment consisting of identical parallel machines, where the jobs are subject to processing time variability. Furthermore, the machines are subject to random breakdowns with known up- and down-time probability distributions. The performance measure of interest is the expected total tardiness. We model the uncertainty in the system using a discrete set of scenarios. We develop an integer programming model that can handle small-size problems without machine breakdowns to generate robust and stable schedules. We then propose a heuristic algorithm that can also handle large problems with machine breakdowns. Our computational experiments indicate that the performance of the proposed algorithms are promising. This research is funded by The Scientific And Technological Research Council Of Turkey (TUBITAK).

2 - Robust Resource Allocation in Resource-Constrained Projects with Discounted Cash Flows
Yangyang Liang

Most research on the problem of max-npv is extensively focused on a static and deterministic environment with perfect information, but in reality, projects are much subjected to various uncertainties during execution. Thus it is crucial to generate a robust baseline schedule to guarantee cash flows to be paid according to the original plan as well as possible. The objective of our research is to develop procedures for allocating resources to activities for a given baseline schedule to generate a stable pre-schedule through minimizing the stability cost (sc) with discounted cash flows. Two procedures are proposed for resource allocation against duration variability, lower bounds for schedule stability are obtained by a simulated annealing algorithm. Extensive results of the experimental application reflect that the procedure of modified MOBO not only can generate a stable baseline schedule in practice but also has remarkable performance with respect to the net present value in the low, medium and high degree of uncertainty.

3 - Reliable Shortest Path Problems
André Chassein, Michael Hopf, Marc Goerigk

The shortest path problem is one of the most studied combinatorial optimization problems with a wide range of applications, such as routing in street networks. As street networks are typically affected by uncertainty, shortest path problems are well-suited for robust optimization approaches that aim at finding solutions that perform well under the presence of uncertain elements.

We consider shortest path problems where arc lengths are uncertain. A common assumption is that they belong to some uncertainty set or are described as random variables. The resulting robust problem is called reliable shortest path problem in the literature. We define the quadratic shortest path problem and discuss the relationship between these two. Further, we show APX hardness for the most general version of the problem, and present amongst other results special cases that can be solved in polynomial time.

Finally, we considerably improve an existing algorithm for the reliable shortest path problem that is based on the idea to interpret the problem as a bicriteria optimization problem. In computational experiments we compare the performance of the improved algorithm with existing algorithms.

4 - Robust Optimal Strategy Algorithm Under Travel Time Uncertainty

Chungmok Lee

Transit line planning problem (TLP) is to determine an optimal operation frequencies of public transportation (e.g., buses, subways) while minimizing the total travel times. The problem was often presented as a two-player game in the previous studies where the city-wide decision is depending on the behavior of travelers that can be modeled as an optimal routing strategy. Any traveller will navigate by an optimal strategy which consists of multiple transportations and routes under given deterministic travel times. However, an optimal strategy based on the deterministic travel times often results in unrealistic routes since city travelers implicitly take into account the uncertain travel times when establishing the optimal routes. In this talk, an optimal route strategy concerning uncertain travel times will be presented. The proposed method extends the well-known algorithm for the optimal route strategy so does not escalate the complexity of the algorithm. Computational experiments will also be presented by using real world test cases.

■ MA-31

Monday, 8:30-10:00 - John Anderson JA5.04, Level 5

Stochastic Modeling and Simulation 1

Stream: Stochastic Modeling and Simulation in Engineering, Management and Science
Invited session
Chair: *Zeev (Vladimir) Volkovich*

1 - On the monotonicity of statistical ranking & selection metrics

Michael Fu, *Yijie Peng*, *Chun-Hung Chen*, *Jianqiang Hu*

For statistical ranking & selection, it is natural to suppose that more sampling leads to better results, but we show that this need not be the case for several commonly used metrics such as the probability of correct selection (PCS). We begin with a simple counterexample to illustrate the phenomenon. We then characterize the general setting where the PCS decreases when popular sampling allocation procedures are followed. We identify the source of non-monotonicity, provide a new sampling allocation method to eliminate it, and present numerical examples, as well as extensions.

2 - A Model Selection Method for Heavy-tailed Clustering

Zeev (Vladimir) Volkovich, *Dvora Toledano-Kitai*

Mixtures of the multivariate Gaussian distribution have can be applied to approximate distributional forms arising in clustering. However, the tails of the used Gaussian distributions often do not reflect the real data structure as being suggestively shorter than actual ones. In this paper we propose an approach to evaluate the components quantity in clustering based on mixtures of elliptical distributions. Estimation of the parameters is provided via an EM algorithm with a specific emphasis on multivariate Laplace and Student distributions. Inference is then used to cover the case of mixtures of such multiple scaled distributions for application to clustering. Possible numbers of clusters are compared from the stability standpoint where closeness of clustered samples is evaluated by means of the geodesic distance defined on an appropriate manifold. Clusters quantity exhibiting the most stable behavior is accepted as an estimation of the number of clusters in the data. Assessments of simulated and real data resolve the improvement in measures of freedom and flexibility in modelling of differing tail behavior.

■ MA-32

Monday, 8:30-10:00 - John Anderson JA5.05, Level 5

AHP/ANP 02

Stream: Analytic Hierarchy/Network Process
Invited session
Chair: *Y. Ilker Topcu*

1 - International Market Selection for Turkish Natural Olive Production

Baris Carikci, *Derya Cabbar*

The production of Turkish olive oil will increase due to new olive trees planted in the recent 10 years. Although there has been a sharp rise of olive oil consumption within in Turkey, Turkey will have a big amount of olive oil surplus in the following years. Turkey olive producers have to find export markets for their surplus. In this research the would-be target countries are found by using AHP and TOPSIS. Their outcomes are compared and target markets for the olive porducers are recommended.

2 - AHP Application for Customer Segmentation in Banking Industry

Serkan Sengul, *Gulgun Kayakutlu*, *Irem Duzdar*

Financial corporations consider knowledge management as one a great support for business development. As one of the most valuable tools of knowledge management, the segmentation has been a topic of interest for some years upon which plenty of academics and marketing managers have been dwelling. Such questions as what sort of marketing strategies are to be applied for certain customers, how much investments would be beneficial per customer and which marketing campaign should be targeted for each customer segment. One of the biggest challenges that the banking industry face today is how to gain an advantage over competitors in satisfying customer needs. Segmentation may also contribute for satisfaction indices within the scope of making the customer feel special. Thus, managers make more effective and profitable strategies. This paper aims at explaining the priorities for the criteria of customer segmentation in banking industry. These criteria will be evaluated using the Analytical Hierarchy Process to give an evaluation index for a Turkish Bank. This study will allow constructing strategies using segmentation perspective leading different approaches for customers with different performances.

3 - An Integrated AHP and VIKOR Approach for Excavator Selection in Open Pit Mining

Ayse Nur Adiguzel Tuylu, *Yakup Celikbilek*

Some mistakes while making important decisions in the mining sector can create very serious problems in terms of business cost, time and safety. In addition, giving the wrong decisions impacts effective, sustainable, succesfull, profitability etc. which are directly related with the production of mining. Using an effective decision making method in the stage of decision making is necessary minimize these problems as much as possible. Selections of equipments and machines used in underground and open pit mines are some of these important decisions. In the selection of the excavator which is one of the mining machinery used in open pit mining, lots of criteria which have various importance should be considered such as being in the other construction machines. We will consult with experts and do literature review to assess these criteria. In the literature, fuzzy decision making methods in decision making problems, particularly involving linguistic variables were obtained successful results applying to various problems. In this study, the selection problem of the excavator solved with an integrated AHP and VIKOR approach under fuzzy environment.

4 - A Multi-Attribute Decision Support Model for the Recommendation of Touristic Attractions

Y. Ilker Topcu, *Sait Gül*

People who wish to join a touristic activity or travel for recreation or leisure purposes rarely have certain information about available travel destinations, group tours, and touristic events. Furthermore, they have their own personal expectations and preferences, especially regarding time and budget limitations. Therefore, they have to collect information about traveling. No one wants to spend her/his limited time collecting information instead of having the travel itself. Besides the individualistic dimensions of tourism planning and marketing studies have a significant importance on national economies all over the world, particularly for nations whose tourism income has become a bigger share of their total national income. Because of these reasons, the determination of the most appropriate touristic attraction for the tourist candidate's preferences, opinions and expectations can be a convenient insight for introducing, marketing, and planning touristic activities. This study aims to develop a personalized touristic attraction recommendation model for tourist candidates with regards their personal expectations and preferences. AHP is used for prioritizing the related criteria obtained from the tourist candidates. TOPSIS is used for assessing global performance of each alternative. The final suggestion becomes a recommendation to the tourist candidate with the most appropriate attraction alternative.

■ MA-33

Monday, 8:30-10:00 - John Anderson JA5.06, Level 5

Complementarity Problems, Variational Inequalities and Equilibrium

Stream: Mathematical Programming
Invited session
Chair: *Sandor Zoltan Nemeth*

1 - Bifurcations of 2-dimensional projected systems and vaccinating games

Monica-Gabriela Cojocaru

Work on modelling vaccinating behaviour has been conducted forcefully during the last decade, and started with a few papers in mid 80's. Modelling probabilities of vaccinating among groups of populations is of importance since vaccinating is a voluntary practice, and each individual, or groups of individuals can decide to vaccinate or not, independent of the availability of particular vaccines. In this work we merge an existing model of a vaccinating game in a majority/minority population with the investigations of effects upon equilibrium vaccinating strategies given by parameter changes in the model. Specifically, we will use a constrained dynamics together with classic notions in bifurcation theory to investigate changes in vaccinating decisions and overall vaccine coverage. We present here our preliminary results.

2 - Reduction of dimension of the upper level problem in a bilevel programming model

Vyacheslav Kalashnikov, Nataliya Kalashnykova

When we study value chains (e.g., natural gas value chains), the general rule usually is: decisions are made by different parties along the chain, and these parties have often different, even opposed goals. Bilevel programming is especially relevant in the case of the interaction between a Natural Gas Shipping Company (NGSC) and a Pipeline Operating Company (POC). The first one owns the gas since the moment it becomes a consumption-grade fuel and sells it to Local Distributing Companies. In order to avoid imbalance, the POC is allowed to apply control mechanisms in order to discourage abusive practices (the so called arbitrage) on part of the NGSCs. Prices induce us into the area of stochastic programming instead of the deterministic approach. The formulated bilevel problem is reduced to an also bilevel problem but with linear constraints. However, this reduction involves many artificial variables, on the one hand, and generation of a lot of scenarios to apply the essentially stochastic tools, on the other hand. The latter makes the dimension of the upper level problem simply unbearable burden even for the most modern powerful PC systems. The aim of this paper is a mathematical formalization of the task of reduction of the upper level problem's dimension without affecting the optimal solution of the original bilevel programming problem. The latter is achieved by introducing an extra follower and solving the lower level equilibrium problem (MPEC).

3 - The extended Lorentz cone a tool for solving equilibrium problems

Sandor Zoltan Nemeth, Guohan Zhang

We extend the notion of a Lorentz cone in a Euclidean space as follows: we divide the index set corresponding to the coordinates of points in two disjoint classes. By definition a point belongs to an extended Lorentz cone associated with this division, if the coordinates corresponding to one class are at least as large as the norm of the vector formed by the coordinates corresponding to the other class. We call a closed convex set isotone projection set with respect to a pointed closed convex cone if the projection onto the set is isotone (i.e., order preserving) with respect to the partial order defined by the cone. We determine the isotone projection sets with respect to an extended Lorentz cone. This study is motivated by solving complementarity problems and variational inequalities via monotone iterations.

■ MA-34

Monday, 8:30-10:00 - John Anderson JA5.07, Level 5

Techniques for Global Optimization

Stream: Nonlinear Programming
Invited session

Chair: *Ana Maria A.C. Rocha*
Chair: *Edite M.G.P. Fernandes*

1 - Firefly Penalty-based Algorithm for Bound Constrained Mixed-Integer Nonlinear Programming

Ana Maria A.C. Rocha, M. Fernanda P. Costa, Rogério B. Francisco, Edite M.G.P. Fernandes

This paper aims to extend the firefly algorithm (FA) to solve bound constrained mixed-integer nonlinear programming (MINLP) problems. An exact penalty continuous formulation of the MINLP problem is used. The continuous penalty problem comes out by relaxing the integrality constraints and by adding a penalty term to the objective function that aims to penalize integrality constraint violation. A new hyperbolic tangent function-based penalty term is proposed. We have proved that the penalty can be used to define the continuous penalty problem, in the sense that it is equivalent to the MINLP problem. The solutions of the penalty problem are obtained using a variant of the metaheuristic FA for global optimization. The numerical experiments with a set of benchmark problems show that the firefly penalty-based algorithm is competitive with a deterministic-based penalty algorithm.

2 - GRASP Solutions to Global Mixed Integer Nonlinear Optimization Problems

Joao Lauro D. Faco', Mauricio Resende, Ricardo Silva

The method Continuous-GRASP solves efficiently constrained global optimization problems by adapting the greedy randomized adaptive search procedure (GRASP) of Feo and Resende. A new version considering discrete and continuous variables is presented. GRASP random search and local improvement phases use simultaneously a discrete and a continuous set. The linear or nonlinear constraints are incorporated to the objective-function by quadratic penalty terms in C-GRASP. Difficult MINLP problems that have been solved this way are presented.

3 - Effects of Uncertainty Issues to Desirability Functions Optimization

Basak Akteke-Ozturk

Desirability functions approach is widely used in multi-response design (surface or nonsurface) optimization. The uncertainty associated with the fitted-response surface model is known as model uncertainty. There are two aspects related with this: responses' models differ in terms of the quality of predictions (variance due to uncertainty in the regression coefficients i.e., a response model predicts better) or responses' models are characterized by unequal sensitivity to uncontrollable variables (robustness i.e., a response model is insensitive). We discuss these aspects to extend the research results obtained in related optimization areas.

■ MA-35

Monday, 8:30-10:00 - Colville C429, Level 4

DEA applications: finance

Stream: DEA and Performance Measurement
Invited session
Chair: *Mohsen Afsharian*

1 - FDI and the World Technology Frontier

Elina Berghäll

The link between foreign direct investment and the world technology frontier (WTF) is strong in the theoretical and empirical literature. Considering the data constraints on global frontier comparisons, I explore the ability of FDI to proxy the WTF. I apply DEA and order-m methodology to an unbalanced panel of Finnish ICT manufacturing firms in 1990-2003, and industry level EU KLEMS data. Since results show domestic firms slightly more efficient than foreign firms, foreign firm efficiency does not proxy the WTF. I conclude that when the gap is to the benefit of domestic firms, and cost and market size motives are not prevalent, the comparison can confirm the technology seeking motive of inward FDI, which in itself suggests proximity of domestic firms to the WTF.

2 - Mission drift or Specialization: Determinants of Financial and Social Efficiency of Microfinance Institutions in Ecuador
Cristina Nataly Cadena Palacios

The research aims to analyze which are the factors and determinants that influences financial and social performance of microfinance institutions in Ecuador using as a unit of analysis institutions members of Red Financiera Rural a National Network of microfinance in the country. The methodology applied in this paper is a second-stage Data Envelopment Analysis (DEA) to measure efficiency in terms of sustainability and outreach using a balanced panel data of 34 MFIs for the period 2009-2012. The analysis differs from previous studies because of the context of maximum legal interest rates and changes in regulation that have taken place in recent years in the country and because we explore the cost structure in estimating efficiency scores. Preliminary results shows that the industry have moved up-market to segments that are more profitable but achieving financial and social efficiency are not mutually exclusive.

3 - Managerial Efficiency under Centralized Management — An Incentive-based Approach with an Empirical Illustration to a German Retail Bank
Mohsen Afsharian, Heinz Ahn

In many real world benchmarking systems, there are situations in which decision making units (DMUs) fall under the umbrella of a centralized management that oversees them. The central decision maker of such an organization often applies a common set of preferences not only to improve the overall performance of the whole system but also the level of learning, coordination and motivation among the DMUs. This paper presents a data envelopment analysis (DEA) controlling approach to construct an incentive mechanism under centralized management. Within this framework, it is assumed that some variables are controlled by the central management to promote efficiency and effectiveness with regard to the corporate strategy and overall goals of the organization. The suggested incentive-based approach will be illustrated by means of a real-world example from banking.

■ MA-36

Monday, 8:30-10:00 - Colville C430, Level 4

Additional Educational Activities for OR

Stream: Initiatives for OR Education
Invited session
Chair: *Kseniia Ilchenko*
Chair: *Oleksii Molchanovskyi*
Chair: *Yuliia Puzanova*

1 - Collaborative Group Formation in Moocs Using Particle Swarm Optimization Method
Deller Ferreira, Matheus Ullmann, Celso Camilo-Junior, Samuel Caetano, Lucas de Assis Rosa

In this work we developed an algorithm to form collaborative groups on Massive Online Open Courses (Moocs) using Particle Swarm Optimization (PSO) method. Group learning principles are used in this work as an attempt to overcome the dichotomy that exists between the collective, which involves the formation of an online learning community on a massive scale, and the individual, with different interests, prior knowledge and expectations. The proposed PSO algorithm accomplishes the task of forming groups based on two criteria, level of knowledge and interest, thus forming groups with different levels and similar interests, providing better students' interactions and knowledge construction. Results of computational tests showed that the algorithm can meet the criteria for grouping in a satisfactory computation time and it is more efficient than algortithms for group formation commonly approached in the literature. Computational tests have also shown that the algorithm is robust taking into account various data sets and variations of iteractions.

This work is partially supported by CNPq.

2 - Creating possibilities for open and unlimited OR education: the first Ukrainian Massive Open Online Courses platform "Prometheus'
Oleksii Molchanovskyi, Ivan Primachenko

The talk will introduce the experience of creating and running the first Ukrainian Massive Open Online Courses (MOOC) platform "Prometheus'. The platform was founded in October, 2014, as a non-profit non-governmental organization in Kyiv, Ukraine. Main goal of the platform is to develop an open space for any of Ukrainian universities, schools, organizations and single persons to create their own MOOCs. We as organizers of the Prometheus are eager to run courses that belongs to the OR field and to other closely related fields, such as business analytics, logistics, finance, smart cities and many others. Particularly, in the first half of 2015 we plan to start on the platform a Business Analytics course. During our presentation in EURO conference we are going to discuss a possibility for global OR community to participate in the process of development thematic OR MOOC environment in Ukraine in order to highly increase quality of education of Ukrainian students and professionals in the relevant fields.

3 - OR/MS EDUCATION: Good Practices and International Cooperation over the 2003-2012 decade
Joao Miranda, Ana Paula Teixeira

A previous overview of good practices in OR/MS Education during the last decade is extended to the projects on behalf of the Education, Audiovisual and Culture Executive Agency (EACEA) of the European Commission. Beyond the talks on OR/MS education that occurred during relevant conference series both at OR/MS national or international level, the related projects developed under the EACEA umbrella for higher education, school education, and vocational training are also considered. The purposes are to reinforce the insight of the main trends on OR/MS education, to outline possible pathways in the years to come, and to further contribute to the European higher education area in OR/MS. The main characteristics of the good practices and international cooperation in OR/MS education are addressed, namely, classroom approaches, courses design, courses assessment, and also the applications of OR/MS tools on Education, such as Data Envelopment Analysis (DEA), Modeling, Scheduling/Timetables, Decision Support Systems (DSS), and Routing for school transportation. The impact in the enrolment of pre-university students, the retention of first year students, the OR/MS courses in Engineering, Management and Exact Science programs, and the transition and retention of graduates onto SME is also aimed.

4 - Teaching Simulation to Management Students - the Case for Cases
Nicky Yates

Many postgraduate management students do not have a strong quantitative background and can find learning technical subjects such as simulation abstract and challenging. Textbook examples are obviously manufactured and do not highlight the relevance and power of simulation as a tool for solving real world problems. Case studies offer a solution demonstrating the pertinence of the method and illustrating the kinds of problems that it can be used to solve. Excellent teaching case simulations not only address an example of a tangible business problem but are also accessible, presenting a model that is not too difficult to build and run. MSc thesis projects provide a rich source of material for developing such case studies. These simulations are simple enough to be adapted for use within a teaching session but also solve challenges encountered by a wide range of organisations. This paper presents examples of projects and how they have been converted into useable teaching case studies. Through solving the cases students develop their skills in tools and techniques needed to build simulation models but also determine how to use these models to reach defensible solutions to these business problems. In addition the simulations can be used to explore validation, simulation error and accuracy, handling data and use of empirical and theoretical probability distributions. The case study shows directly why each of these is necessary to produce robust results and thus make better decisions.

■ MA-37

Monday, 8:30-10:00 - Colville C411, Level 4

Optimization for Sustainable Development 1

Stream: Optimization for Sustainable Development
Invited session
Chair: *Herman Mawengkang*
Chair: *Gerhard-Wilhelm Weber*

1 - An Optimization Model for Sustainable Crude Palm Oil Industry
Hendaru Sadyadharma

The crude palm oil industry plays an important role for economic development. There can be substitute products derived from petrochemicals. Due to an increasing environmental awareness, these products have a bright future. Despite obvious benefits of this industrial development, it contributes to environmental degradation from both input and output sides of its activities. On the input side, a crude palm oil mill uses much water in the production process and it consumes high energy. On the output side, the manufacturing process generates large quantity of waste water, solid waste/ by-product and air pollution. This paper addresses a multi-objective stochastic programming model of the sustainable production planning of crude palm oil. The model takes into account conflicting goals such as return and financial risk and environmental costs. The uncertainty comes from the price of crude palm oil. Starting from it two single objective models are formulated: a maximum expected return model and a minimum financial risk (pollution penalties) model. We transform the stochastic programming model into a deterministic multi-objective model using sampling average approach. Then we solve the result model using an interactive method.

2 - Greenhouse gases emission reduction from the logistic perspective
Juraj Pekár, Zuzana Čičková, Ivan Brezina

The greenhouse emissions still remain a worldwide problem. Their reduction significantly affects additional economic effects for the distribution companies and also for whole public sector and it can be considered as one of the key areas of public environmental policy. Transport is clearly one of those areas, which contributes significantly to their production. Therefore it is important to use integrated approaches aimed at CO2 emissions reduction. The goal is to model such conditions, where the state institutions not only provide legislative framework, but also they implement practical decision strategy in cooperation with other companies in deployment of distribution centers and transport organization. Efficiency in in the field of transportation can be supported by different quantitative approaches. Those approaches are mainly supported by models of mathematical programming and corresponding problems could be solved with the help of appropriate software. Presented analysis is aimed at use of optimization approaches for transport planning focused on routing optimization with respect to CO2 emissions production by using various types of vehicles with different maximal capacities and fuel consumptions.

3 - Combining Quantitative and Qualitative Criteria: Selecting Water Management Projects
Uros Rajkovic, Marjan Brelih, Tomaz Ruzič, Vladislav Rajkovic

This contribution presents an innovative approach to selection of investment projects for effective water management and management of water distribution systems. Goals, which we pursue in this kind of project, are management of the client's assets, reduced production of the production-technical risks, minimizing the costs of the current investment maintenance and reduced operating costs. Selection of the suitable projects must meet the main criteria, such as financial aspect of the project, final success in accordance with contract requirements and deadlines, and dissemination of knowledge in co-operation with the client. The list of selection criteria was determined by an expert group. The goal was to design a multi-criteria decision model that takes into account both quantitative and qualitative criteria. Our model combines different types of utility functions, such as weighted sum or simple what-if rules. It also enables defining conversion functions from qualitative to quantitative value domains and back. The result is an overall assessment for each project consisting of both discrete class value and a numeric grade that helps distinguish small differences among options that fall in the same class. This evaluation is based on complex rules and is derived from original input data. The proposed approach makes it possible to carry out different types of analysis. Such a tool helps the decision maker to better understand the results and to make better decisions.

Monday, 8:30-10:00 - Colville C410, Level 4

Humanitarian Operations with Uncertain Aspects

Stream: Humanitarian Applications
Invited session
Chair: *Maria Besiou*

1 - Volunteer Management in Charity Storehouses
Maria Besiou, Alfonso Pedraza-Martinez

We study volunteer management at a large faith-based organization. The whole supply chain operates exclusively with volunteers (from supply to delivery). We focus our study on the preparation of the beneficiaries' orders by volunteers in a storehouse. There are different categories of volunteers; some are more experienced while others may work in the system for the first time. The size of the beneficiaries' orders, the time that the volunteers need to work on them and the number of volunteers that will be preparing the orders are stochastic. The demand of the beneficiaries is known in advance and the funding is deterministic. Using empirical data we build a system dynamics model to explore the drivers of on-time order fulfillment at the storehouse level.

2 - Understanding Fundraising for Operational Expenditures in International Humanitarian Aid
Laura Turrini, Maria Besiou, Joern Meissner

Effectiveness of humanitarian programs depends on funding. Based on the operational needs of the programs, international humanitarian organizations (IHOs) estimate the operational expenditures and then they appeal for donations. Donations affect IHOs' services and the number of beneficiaries that they will be able to reach. Generally, demand for humanitarian help worldwide exceeds the donations raised. Still, while some humanitarian programs are underfunded, others raise so many donations that they are overfunded. In this paper, using multiple regression analysis, we aim to shed more light on the operational implications of fundraising and on the possible improvement of fundraising for operational expenditures for humanitarian programs. Firstly, the paper analyzes how IHOs decide on the operational expenditures included in budget appeals. Secondly, we study whether some operational expenditures require higher fundraising efforts than others. Thirdly, we estimate the responsiveness of donations to a number of variables including fundraising cost, budget appeal and area/country where the program takes place to help IHOs improve their fundraising strategies. Finally, we analyze the drivers of the actual operational expenditures made by the IHOs and look at what drives the gap between the budgeted and the actual operational expenditures. We use data of one of the largest IHOs, the International Federation of Red Cross and Red Crescent Societies.

3 - Multiple-Criteria Decision Analysis in Humanitarian Supply Chains
Sahar Validi, Maria Besiou

Humanitarian supply chains have to be designed and adapt to the uncertain and dynamic environment in which they operate. Their complexity increases even more by the multiple stakeholders with conflicting goals that affect their operations. The supply chain performance is significantly affected by the structure of the logistics network. Designing and managing such a network is a very challenging task and requires considering conflicting objectives and many different criteria. Operations Research and Management Science is contributing to humanitarian supply chain management in a rapidly growingly fashion; yet a literature review shows very limited use of Multi-Criteria Decision-Making (MCDM) techniques in modelling, designing and managing these supply chains. MCDM is often considered a complex and dynamic process through which more than one single objective, more than one single criteria and more than one single decision maker can be involved and considered throughout the whole process. This paper reviews the existing literature on MCDM research and publications in humanitarian supply chain management to date. Through the content analysis, research gaps in the subject area are identified and proposed for future research.

4 - Saving Lives with Operations Research: Models to Improve HIV Resource Allocation
Margaret L. Brandeau, Sabina Alistar

Public health budgets, including budget for control of HIV/AIDS, are limited, so it is essential to use existing disease control funds in the most effective manner. This talk describes our research on effective allocation of HIV control resources. Our work aims to bridge the gap between theory and practice. Toward this end, our work has focused on developing theory, performing practical analyses, and empowering decision makers. This talk summarizes our recent work in each of these areas. Specifically, we describe our work on the development of theory that can generate insight into appropriate HIV resource allocations; practical analyses to address relevant HIV resource allocation problems in a timely fashion; and a planning tool for use by decision makers who must allocate HIV prevention and treatment resources. We conclude with discussion of the broader decision making context and key areas for further research.

■ MA-39

Monday, 8:30-10:00 - Colville C405, Level 4

Risk and Policy Analytics I

Stream: Decision Processes
Invited session
Chair: *Ashwani Kumar*

1 - Applying analytics on public transport data to optimize cycling policies in Singapore
Ashwani Kumar, Viet Anh Nguyen, Kwong Meng Teo

This paper uses data analytics techniques on fare-card data to suggest policies for commuter cycling. Peak-hour week-day traffic congestion is a common challenge in urban mobility. Promotion of commuter cycling can help in alleviating this problem in many cities. This paper uses fare-card data to assess the commuter cycling potential in Singapore. A spatio-temporal analysis of the farecard data helps in suggesting policies like cycling towns and links for the first-mile and end-to-end cycling. Further, an optimization model is developed to make efficient policy choices for a given budget.

2 - Robust performance comparison: some ratio-based analyses of Scottish Health Boards
Laura Schang, Yrjänä Hynninen, Alec Morton, Ahti Salo

Rankings of healthcare performance typically embed contentious assumptions: although many comparative measures are constructed as ratios, the choice of denominator is often ambiguous. Numerators are often composite indicators, yet it is unclear how constituent indicators should be weighted to obtain a single number. We aim to explore healthcare applications of an approach to ranking which is robust to alternative modelling assumptions of this sort. We adopt a ratio-based efficiency (REA) technique for healthcare quality comparisons of Scottish Health Boards. The REA approach permits pairwise one-on-one comparisons of ratios with multiple denominators and numerators which consider all feasible weights. As a quality measure, we examine the number of adverse events patients experience before, during and after a hospital stay relative to hospitalised and general populations. The results show possible rankings of Scottish Health Boards (displayed in a unified way as dominance relation). This allows one to identify Boards which cannot be ranked, say, worse than 4th or better than 7th. Such rankings give policy-makers a sense of the uncertainty around ranks, and the extent to which action is warranted. Rankings are often sensitive to choices of weights and the REA approach identifies those ranking judgements one can have confidence in.

3 - A decision-analytic framework for the identification of cost-effective diagnostic testing strategies
Ahti Salo, Yrjänä Hynninen, Eeva Vilkkumaa

When choosing how to treat a patient, it is important to make a correct diagnosis of the patient's state of health. The likelihood of a correct diagnosis can be increased by carrying out diagnostic tests. However, because such tests are not totally reliable and consume resources, they should only be carried out if the increase in utility resulting from making a better-informed treatment decision can be expected to offset the costs of testing. In this paper, we present a decision-analytic framework for identifying cost-effective testing strategies. In particular, depending on the patient's initial probability of having a disease, our framework helps determine (i) which tests to carry out and in which order and, given the test results so far, (ii) when to stop testing and

decide on a treatment action. The problem of finding an optimal testing strategy is modeled as a decision tree in which the probability of a patient having a disease is updated based on the test results using Bayesian methods. We show how the optimal testing strategy (i.e. the optimal path through the tree) can be solved with a reasonable computational effort using a dynamic programming algorithm. Besides identifying optimal testing strategies, we discuss how our framework can be used to support the cost-effectiveness analyses of adopting new testing technologies.

4 - Informing rational decisions about psychoactive, prescription and over-the-counter drugs
Larry Phillips

The harm of psychoactive drugs, and the benefit-risk balance of medicinal products now attract world-wide attention of decision makers, as research demonstrates the feasibility and desirability of quantitative modelling to aid better decisions about drugs.

This talk will explore the main findings of four recent European research programmes: 1. The Independent Scientific Committee on Drugs examined the harm in the UK, of 20 psychoactive substances on 16 effects to users and others; alcohol emerged as most harmful. A separate group replicated the findings for the EU. A third model, examined the harms of nicotine. 2. The Benefit-Risk Project sponsored by the European Medicines Agency modelled five new drugs and recommended steps to improve the transparency and communicability of decisions. 3. The IMI-PROTECT project, sponsored by the European Community and the European Federation of Pharmaceutical Industries and Associations, modelled six drugs approved in the past, and developed best-practice guidelines. 4. Reckitt Benckiser sponsored research that prioritised the benefit-risk balance of over-the-counter analgesics.

All these models required data about the drugs' effects and judgements about their relevance, which required a socio-technical approach: multi-criteria decision analysis for combining evaluations of the effects, and facilitated workshops for sharing data and experiences of experts so they could construct judgements about relevance.

■ MA-41

Monday, 8:30-10:00 - Colville C512, Level 5

Complex Preference Learning I

Stream: Multiple Criteria Decision Aiding
Invited session
Chair: *Salvatore Corrente*

1 - Robust multi-criteria sorting with the outranking preference model and characteristic profiles
Milosz Kadzinski, Tommi Tervonen, José Rui Figueira

We present a new multiple criteria sorting approach that uses characteristic profiles for defining the classes and outranking relation as the preference model, similarly to the Electre Tri-C method. We reformulate the conditions for the worst and best class assignments of Electre Tri-C to increase comprehensibility of the method and interpretability of the results it delivers. Then, we present a disaggregation procedure for inferring the set of outranking models compatible with the given preference information, and use the set in deriving, for each decision alternative, the necessary and possible assignments. Furthermore, we introduce simplified assignment procedures and prove that they maintain a no class jumps-property in the possible assignments. Application of the proposed approach is demonstrated by classifying 40 land zones in 4 classes representing different risk levels.

2 - A patient-centered MCDA model for improving antibiotic prescriptions
Souhir Ben souissi, Ornella Moses, Mourad Abed, El Hiki Lahcen, Marc Pirlot

Inappropriate prescriptions and overuse of antibiotics are the two main reasons in the continuous increasing danger of the emergence of antibiotic resistance. To cope with this serious issue, physicians first resorted to using guidelines especially for hospital prescriptions. The main drawback of guidelines is that recommendations are explicit, unexplained and difficult to maintain. The present work aims at designing a MCDA model that allows to match two bodies of knowledge (encoded as ontologies), one relative to the patient and the other to antibiotics pharmacology. We propose an Electre-Tri like MCDA procedure to sort the suitable antibiotics in three categories (Recommended,

Possible, To Be Avoided) taking into account (i) the patient characteristics, i.e. bacterial infection pathogens and host features (allergy, insufficiencies .), (ii) the antibiotic characteristics, i.e. side effects and priority (first-line or restricted use in order to avoid the emergence of antibiotic resistance). The sorting model parameters are determined and adjusted in order to fit with the guidelines used in a Belgian hospital. A model validation process is being conducted with the collaboration of the hospital infectious diseases department.

3 - Addressing weaknesses in pairwise comparison based prioritization methods - can the spanning tree approach help?
Michele Lundy, Sajid Siraj, Salvatore Greco

Pairwise comparison is a well-known approach to elicit preferences from a decision maker. In this paper, we formalize the equivalence of the two methods of row geometric mean and the geometric mean of all spanning trees. We then discuss other prioritization methods - identifying a number of desirable properties and identifying weaknesses in the existing approaches. We assess the role of the spanning trees approach in addressing these weaknesses — showing that the approach satisfies the assessment criteria for prioritization methods, is applicable to both complete and incomplete pairwise comparison matrices, and also has the ability to perform enhanced sensitivity analysis.

4 - Assessing Behavioral Deviation in Primary Schools by Multiple-Criteria Decision Models
Vladislav Rajkovič, Ursa Sustarsic

This contribution presents a development of a evaluation support system for quick evaluation of various difficulties in primary school children which consists of screening test and six multi-criteria decision support models. First step consists of a screening test, which identifies children at risk. In the second step teacher assesses identified children in detail on additional 37 behavior deviation criteria. This assessment is input data for six multi-criteria decision support models that detects signs of 6 difficulties: attention deficit hyperactivity, anxiety, autism, emotional and behavioral difficulties, signs of depression and learning difficulties. Evaluation support system results provide teachers support on deciding further course of action. Evaluation models were developed with two software tools, with DEX method in DEXi and MAUT model in HiView. Goal was to develop a practical tool to help teachers evaluate difficulties, to check model accuracy of each method and check possibilities of practical use. This evaluation system is a proposal for a systematic tool to identify children with special needs in Slovenian primary schools.

■ MA-42
Monday, 8:30-10:00 - McCance MC301, Level 3

Case studies in OR/Analytics 1: Overview/Public Sector

Stream: Case Studies in OR / Analytics
Invited session
Chair: *Sue Merchant*

1 - Reassessing the Scope of OR Practice: the Influences of Problem Structuring Methods and the Analytics Movement
John Ranyard, Robert Fildes

Whilst OR originally sprang from practical problems, the long-acknowledged gap between research and the needs of practitioners and client organisations remains wide. In addition the boundaries of OR, particularly with regard to strategic problems are contested. As a result OR practice may become marginalised. Recent surveys of OR practice show that the methods used are largely unchanged and that long-known barriers to the use of OR persist. Also the OR label is unhelpful to practitioners and often not used. Despite this potential marginalization, the scope of OR practice is being extended by the use of Problem Structuring Methods, (PSMs or 'Soft' OR) and the fast-growing Analytics/Big Data movement. A recent IFORS-sponsored survey identified 3 clusters of practitioner: traditional OR, which is successful where practiced, partly through the development of effective client management strategies and is well supported; 'Soft' OR, which has been successful in the UK but is not universally supported

and faces challenges to wider use; and Business Analytics (BA), which is growing rapidly in industry (but not in academia), is better known and understood at Board level than OR and has an overlapping but distinct skill set. OR Societies must address the challenges and opportunities presented by the BA movement, support further development of PSMs and not allow the gap between research and practice to widen further, so as to ensure a healthy future for OR..

2 - Optimising the Efficiency of the National Police Air Service through the Application of Simulation Modelling Tools
Martin Rahman, Gail Mawdsley

In response for a need to establish a cost effective and efficient operating model for the National Police Air Service (NPAS), West Yorkshire Police's Organisational Development team were commissioned to build a simulation model which captures the operational characteristics of the service's fleet of rotary and fixed wing aircraft. This presentation will show how the model works and what opportunities it offers NPAS in terms re-shaping the future of the nation's Police Air Service.

3 - London Fire and Emergency Planning Authority: Making Substantial Financial Savings with Minimal Impact on Cover
Andrew Cooper, Graham Holland

The London Fire and Emergency Planning Authority (LFEPA) needed to achieve savings of £29.5 million in 2013/14 and a further £35.5 million in 2014/15 to meet budget targets set by the Mayor of London. ORH was asked to develop a modelling approach to support LFEPA officers in this task. Over previous years, the authority had already delivered significant savings from back-office functions without touching front-line services, so future savings would need to come largely from operational services provided by the London Fire Brigade (LFB), covering fire stations, appliances and firefighter posts. The aim was to do this with minimal impact on response and risk cover across London. ORH's optimisation model was used to identify options for station configuration and appliance deployment that would minimise the impact on emergency cover while making the required savings. Optimisation criteria and constraints were set by LFB officers. Simulation modelling was undertaken to examine implications for risk cover and response times. A preferred option was identified comprising redeployments and reductions in appliances that could be made to generate the bulk of the savings required while allowing the existing London-wide attendance targets to be maintained. These recommended changes were included in LFEPA's Fifth London Safety Plan. The operational changes, together with other savings, enabled LFEPA to meet the targets to deliver a balanced budget for 2013/14.

4 - Clinical Capacity Planning for the East of England Ambulance Service NHS Trust
Jon Mobbs, Tom Boness

ORH was asked to undertake a review of the service provision for the East of England Ambulance Service NHS Trust (EEAST). The aim was to understand gaps in provision for key performance targets such as response times and call-to-hospital times for stroke and STEMI patients and then determine how to bring the service up to a level specified by internal and external stakeholders.

First a baseline was established by determining the level of service that EEAST was delivering with current working practices and resources. Then the shortfall between this baseline and various stakeholder-defined targets was calculated. Next, we identified gains in performance that could be achieved with current resources by improving working practices and efficiency, before assessing the investment required from the service and the wider health system to fill any remaining gaps.

The study utilised a specialised discrete event simulation model developed in-house by ORH, customised for the review and handed over to EEAST at the end of the project. Following the project, it was used by the service to create performance trajectories based on demand and resourcing forecasts.

The study revealed a series of efficiencies to improve the service and help it to meet the desired performance, including rearranging resource deployments, altering shift timings and simplifying dispatch protocols. These results were used by the service in subsequent discussions with their Clinical Commissioning Groups.

■ MA-43

Monday, 8:30-10:00 - McCance MC303, Level 3

Defence and Security Applications

Stream: Defence and Security Applications
Invited session
Chair: *Ana Isabel Barros*

1 - Socialising SMaRT with the Military
Laura Richards

Effective military capability management and planning is fundamental to ensuring that capabilities are available to meet defence and security requirements now and in the future. This is complicated by a fast paced turnover of staff and equipment. Existing methods for visualising the assessment and maintenance of capabilities over time are static and resource intensive, failing to keep pace with opportunities for change. This presentation will describe how a new Ministry of Defence developed tool, the SMaRT (Sync Matrix and Road mapping Tool), has given rise to a more dynamic form of capability management and planning visualisation, linking research outputs and other opportunities to capability decision points. It will explore core elements of SMaRT, which enables roadmaps or plans to be easily produced, formatted and maintained, including how these elements have been configured to aid the military both in their day-to-day management of existing capabilities and to plan the introduction of replacement and/or new capabilities. How SMaRT was socialised with the user community to foster enthusiasm for its acceptance will be illustrated, and its successful application to enable efficient and timely capability management demonstrated. The presentation will conclude by addressing any issues identified with the use of SMaRT and identifying plans for its future exploitation.

2 - The Swedish Approach to Operations Assessment
Jan Frelin

Operations Assessment for military operations has proven to be a challenging. In meeting these challenges, the Swedish armed forces have used ideas from the management of complex situations, evaluation science and 'soft' operations research in order to devise a new method for operations assessment that suits Sweden's military requirements. These ideas are presented here in an early stage in order to foster debate on possible options for effective operations assessment.

3 - Comparing Apples with Oranges - Auditing Military Capability
Paul Elrick

Each year Dstl supports the armed services in undertaking an audit of their operational capability in order to assess their ability to meet what they are required to do to deliver as part of UK Defence Policy. This exercise is called the Capability Audit and is a predominately judgement based structured assessment of military capability across a range of scenarios (and hence threats) and timeframes. The primary output is a list of capability shortfalls (gaps) across a range of levels (minor to critical) that will then be used to inform capability development, and ultimately investment, decisions. The assessment in the land environment is particularly challenging given the broad range of skills and equipment that together enables land's collective capability. The land audit assesses infantry weapons and armoured vehicles as well as surveillance and communication systems, logistical re-supply equipment and the support provided by military dogs. This paper will explore the strengths and weaknesses of the current process, and discuss the challenges that need to be overcome in order to improve this critical tool in the assessment military capability.

4 - Systems approaches for building a model for defense structures and organizations: a Brazilian perspective
Nilton Lessa, Mischel Carmen N. Belderrain, Osvaldo Catsumi Imamura

In National Defense context, operations planning and capabilities are terms of interest for those who work on the activities related to managing forces and resources, as well as the shape and management of the battlefield and scenario. In this sense, it is important to build a model that allows systemic vision and understanding of constitution of defense capabilities in order to support acquisition and development decisions at strategic and operational levels. This article aims to discuss the nature and relationship between the different types of systems present in the National Defense System and identify systems thinking and systems approaches suitable for understanding the structural and

organizational components of this macro system. Specially, this work is situated in a context with planning guided by the Brazilian National Defense Strategy, which highlights the directives to structure the strategic potential of the armed forces around the concept of capabilities and network-centric joint operations.

■ MA-44

Monday, 8:30-10:00 - McCance MC319, Level 3

Fuzzy Goal Programming

Stream: Fuzzy Decision Support Systems, Soft Computing, Neural Network
Invited session
Chair: *Mariano Jimenez-Lopez*

1 - Defuzzification based on gravity centers for MRP problems with fuzzy lead times
Manuel Díaz-Madroñero, Josefa Mula, Mariano Jimenez-Lopez

In this paper, we propose the use of a defuzzification method based on the searching of gravity centers for a fuzzy goal programming approach to model material requirement planning (MRP) problems with fuzzy lead times. Given each set of values of the fuzzy solutions (z1, z2, z3) correspond to a concrete combination of lead times, we propose to address them as if they were balls in the space with a determined weight. The assigned weight would be the value of the objective function of the MRP model. Finally, the solution would be the closest to the gravity center. This paper has been funded by the Spanish Ministry of Education projects: Design and Management of Global Supply Chains (GLOBOP) (Ref. DPI2012-38061-C02-01) and the ECO2011-26499 project.

2 - A rank-aggregation model and algorithms dealing with partial lists
Mauricio Ruiz-Tagle, Esther Dopazo, María Luisa Martínez

The problem of rank aggregation appears in many applications like meta-search engines, information retrieval, MCDM, etc. It consists on combining several rank-ordered lists of items in a robust way to produce a single consensus ranking. There has been an extensive body of work on this topic, beginning with the works of Borda and Condorcet in Social Choice Theory, and the Arrow's impossibility theorem. The literature review states that there is no aggregate ranking which satisfies simultaneously several necessary fair requirements. Also, a great deal of the literature is concerned with models that assume full lists. Though, a usual situation in real world is when incomplete information arises and only partial rankings may be supplied. We address the general problem of rank aggregation dealing with incomplete information and with the challenge of working with partial lists. It consists on constructing a complete ranking that represents "as best as possible", conflicting and incomplete information given by regards partial rankings according to multiple criteria. We propose a matrix approximation approach to analyze the problem and to derive a complete ranking of the items. Our model is articulated in two steps. An outranking matrix is constructed as a way of collecting relevance information from available data. Secondly, we use fuzzy preference relations theory to derive a priority vector of items. In addition, efficient algorithms are provided to compute the solutions.

3 - Simulation approach to multiobjective fuzzy random linear programming problems
Safari Mukeru

In this paper we discuss an approach based on simulation modelling to solve multiobjective fuzzy random linear programming problems. We offer the decision maker a range of solutions, each being optimal on a subspace of the sample space with positive probability. In this case, the decision maker has the flexibility to compare these solutions and to make possible adjustments until a fully satisfying solution is reached. The approach is particularly interesting in large-size real life problems with the presence of several fuzzy random variables.

4 - ● Fuzzy multi-criteria support for measuring the social sustainability of the Spanish companies from their performance on the GRI indicators.

Mariano Jimenez-Lopez, Amelia Bilbao-Terol, Mar Arenas-Parra, Verónica Cañal, Pablo-Nguema Obama

The concept of Corporate Social Responsibility (CSR) may be defined as the commitment by firms to contribute to sustainable economic development while improving the quality of the life of the workforce as well as the local community and society at large. Socially responsible investment (SRI) looks for companies with good CSR performance. The aim of this work is to design a quantitative method in order to evaluate the social performance, related to the Labor Practices and Decent Work category, of the Spanish companies which compose the IBEX-35. The Global Reporting Initiative (GRI) is the used source, since it provides a framework against which all types of organizations can track and report their economic, environmental and social performance. We have constructed a hierarchical system of the analyzed GRI-category, from which the company scores are obtained. The model addresses the particular preferences of a SR investor by means of the determination of priorities. To do so we use linguistic labels and fuzzy preference relations. In addition, it is designed a model for selecting SR portfolios considering financial objectives and a sustainability objective, that it is handled through the aggregation of the company performance on all aspects inside the category of Labor Practices. We use an extended Goal Programming approach to solve the portfolio selection.

■ MA-45

Monday, 8:30-10:00 - Graham Hills GH514 Lecture Theatre

Routing in Public Transport

Stream: Optimization of Public Transport
Invited session
Chair: *Marie Schmidt*

1 - Public Transit Labeling

Julian Dibbelt, Daniel Delling, Thomas Pajor, Renato Werneck

We study fast journey planning for passengers in large public transit networks. Developing efficient preprocessing-based speedup techniques for this problem has been challenging: current approaches either require massive preprocessing effort or provide limited speedups (over basic query algorithms that require no preprocessing). Leveraging recent advances in Hub Labeling (the fastest algorithm for computing driving directions in road networks) and exploiting domain-specific properties in public transit, we provide simple and efficient algorithms for earliest arrival, profile, and multicriteria search problems. Our approach yields orgin-destination queries that are orders of magnitude faster than the state of the art.

2 - Flow control through shortening of arc lengths with application in public transport

Lisa Thom, Marie Schmidt

In a given transportation network each passenger chooses a path depending on aspects like travel time, price and comfort. Even with optimal line planning there are often parts of the network more frequented than others. One way to reach a more balanced distribution is to make single connections more attractive e.g. by cutting prices. In terms of line planning one would want to shorten some arcs of the change-and-go-graph to control the passenger flow. We investigate the problem to choose arc lengths such that either some predefined paths are shortest paths from their source to their destination and therefore used by the passengers or such that all passengers can choose shortest paths without exceeding given arc capacities. We model these two problems as integer linear programs, show their NP-hardness, discuss some special cases and combine our approaches with methods of line planning.

3 - The Line Planning Routing Game

Marie Schmidt, Philine Gattermann, Alexander Schiewe

We model line planning as a routing game where the passengers are players which aim at minimizing individual objective functions composed of travel time, transfer penalties, and a share of the overall cost of the solution. To find equilibria of this routing game, we use a best-response algorithm. We investigate, under which conditions on the line planning model a passenger's best-response can be computed efficiently and which properties are needed to guarantee convergence of the best-response algorithm. Furthermore, we determine the price of anarchy which bounds the objective value of an equilibrium with respect to a system-optimal solution of the line planning problem. For problems where best-responses cannot be found effciently, we propose heuristic methods. We demonstrate our findings on small examples.

4 - Using Information on Passenger in Public Transport planning

Evelien van der Hurk

Passengers traveling in public transport generate a detailed digital track record of their journey through using automated fare collection systems and carrying mobile devices. This information on passenger behavior has only recently become available to public transport operators. We address the question of how this new information can be used to improve passenger service in in public transportation systems. Specifically, we focus on including passenger behaviour in to public transportation combinatorial optimisation planning models.

■ MA-48

Monday, 8:30-10:00 - Graham Hilils GH510, Level 5

New Developments in Location Analysis

Stream: Location
Contributed session
Chair: *Dmitry Krass*

1 - Stochastic location models with congestion and immobile servers: An overview

Dmitry Krass, Oded Berman

The talk will provide a review and structure for the different models in this field, focusing particularly on the implicit behavioural assumptions. We will discuss some algorithmic challenges, as well as promising directions for new research.

2 - Locating p parallel lines on the plane using minisum and minimax

Jack Brimberg, Robert Schieweck, Anita Schöbel

We examine the problem of locating p parallel lines in the plane to serve a given set of customers. Two objectives are proposed: minimizing a weighted sum of distances from the fixed points (customers) to their closest lines, and minimizing the maximum of these distances. The mathematical model is formulated and properties are analyzed leading to a finite dominating set for each objective. An efficient solution method is proposed. Applications of the model include the location of linear facilities such as roads and also regression analysis.

3 - On sales & service districting problems

Jörg Kalcsics

In sales districting, we have to assign a set of customers, each with a fixed market potential, to the members of the sales force such that each customer has a unique representative and each sales person faces an equitable workload and has an equal income opportunity. Two other important planning criteria are travel distances and clearly defined geographic areas of responsibility. The latter criterion is desired to avoid competition among the sales force and is termed as contiguity. Concerning travel distances, if a sales person visits each customer every day, then the travel time is proportional to the length of a TSP tour. However, the workload of districts is usually balanced over 2-4 weeks, customers may have time windows, tours may include overnight stays, etc., which makes the actual computation of the travel times impossible for large instances. Therefore, districting uses the concept of compactness as a proxy for travel distances. A district is said to be geographically compact if it is round-shaped and undistorted. A similar setting is encountered in service districting.

In sales & service districting, customers are predominantly represented as points and there is no consensus on a common compactness measure or suitable approaches to model contiguity of point sets. In this talk, we want to give an overview of different approaches to measure compactness and assess contiguity, and discuss their strengths and weaknesses when applied to practical problems.

4 - On locating a median line to approximate objects in the plane

Robert Schieweck, Jack Brimberg, Anita Schöbel

We generalize the classical problem of locating a straight line minimizing the sum of weighted distances to a finite number of demand points. In our setting, the demand objects can be compact, convex sets. Distance from a line to a set is taken to be the distance from the line to the norm-closest point of the set. The norm can be arbitrary. Our main result is the existence of an optimal line for the median line location problem with demand sets which is tangent to at least two of the demand sets if a mild general position assumption on the demand sets holds. This gives rise to a simple solution technique running in cubic time with respect to the number of demand sets. The general position assumption can be removed without compromising the running time. Furthermore, we show that convexity of the demand sets can be relaxed to connectedness and even unconnected demand sets can be handled within a running time cubic in the total number of connected components of all demand sets. An application of this solution procedure in the computation of lower bounds for planar projective clustering problems is discussed. It is shown that there is no obvious generalization to higher dimensions, i.e. in dimension d there need not be a median hyperplane tangent to d of the demand sets.

■ MA-49

Monday, 8:30-10:00 - Graham Hills GH511, Level 5

Metaheuristics Analysis, Frameworks and Applications

Stream: Metaheuristics
Invited session
Chair: *Dennis Horstkemper*

1 - Measuring exploration-exploitation behaviour of neighbourhood operators in permutation search spaces

James McDermott

An important theme in research on metaheuristics is the exploration-exploitation trade-off. It is common to say that some neighbourhood (mutation) operators are more explorative, and others more exploitative. We propose a method of making such statements precise, based on the operator's transition matrix. We measure the variance within a single row of the transition matrix (i.e. the probabilities of each state being the successor of the current state). If there is little variance, then all states are likely as the successor, and the operator is similar to random search, so we call the operator explorative. If there is great variance, then the operator is more exploitative.

In previous work we have studied typical operators in search spaces of bitstrings (genetic algorithms) and of trees (genetic programming). Here, we extend the analysis to include operators typical of permutation spaces, as used in TSP and similar problems. Our method allows comparison even between operators on different spaces.

We also now give an improved definition of our measure. The best way to measure variance in a probability distribution is to think of it as inequality. Here, we propose to use a standard statistical measure of inequality, the GINI coefficient.

2 - A component-based evaluation of solution representations for lot-sizing problems

Dennis Horstkemper, Carolin Wagner, Bernd Hellingrath

When encountering very complex planning problems, such as lot-sizing problems within a complex manufacturing network, exact planning methods often are not capable to find solutions in sufficient timeframes. Before resorting to brute force methods, metaheuristics are often capable to find suitable solutions in acceptable timeframes. However, the proper application and adaptation of a metaheuristic for specific planning tasks is still considered a form of art instead of a proper science. Scientists regularly encounter the same problems when having to identify the correct metaheuristic, the correct parametrization and an appropriate fitness function for a specific planning task. Thus, we approach metaheuristics from a component-based viewpoint. We study the different operators and their influence on a metaheuristics problem-solving capabilities. Particularly focus lies on the solution representation of lot-sizing problems. Multiple kinds of metaheuristics are tested

on the publically available datasets provided for lot-sizing problems from Helmut Stadler and Horst Tempelmeier. We use binary and discrete metaheuristics with mostly identical operators for the often used ways to apply population-based metaheuristics on lot-sizing problems: Encoding of the solution as binary setup variables or as discrete lot sizes. Thus, we contribute to the understanding of metaheuristics applied to suchlike problems, decreasing the required effort to apply them to problems in practice.

3 - The JAMES framework: new features and applications

Herman De Beukelaer, Veerle Fack

JAMES is a modern object-oriented Java framework for discrete optimization using local search metaheuristics. This talk addresses new features, including support for efficient delta evaluations and an automated analysis workflow, as well as a case study.

Since local searches inspect sequences of neighbouring solutions, it is not needed to independently evaluate each visited solution. When a move is applied to the current solution, the evaluation can be updated by considering how the solution is changed. Incorporating such delta evaluations often significantly speeds up the optimization process. The analysis tools can be used to compare algorithm performance on a series of problem instances with e.g. different data or objectives. Also, the influence of search parameters can be assessed. An R package is provided with which the results can easily be visualized and further analyzed.

Development of core collections is considered as a case study to demonstrate the new features. This is a combinatorial optimization problem in a genetic context with applications for plant breeding and conservation of genetic resources. The goal is to select a representative subset with minimum redundancy, based on a given distance matrix. Various specific objective functions have been proposed in literature, of different complexity. It is shown how the analysis tools of the JAMES framework can be used to select an appropriate optimization strategy for the different objectives.

4 - Utilization of metaheuristics to generate the Programming Grid of interventions of commercials applied to Digital TV and IPTV

Arthur Gomez, James Gladstone Fagundes Brum

This work presents the use of metaheuristics to generation of the Programming Grid of interventions of commercials applied to Digital TV and IPTV. This problem presents itself in the timeline of the television grid, where are defined the schedules of the interventions, in which the groups of commercials must be displayed. The ordination of commercials, follows a set of requirements and constraints such as, rate of return, adaptation to target audience, utilization of the width of server band, parental rating, number of exhibitions of the commercial, and adequacy to programming. In this context, are considered the problems of Parts Selection and Timetabling for the developing of a memetic algorithm that performs the management of insertion of the commercials in the Programming Grid. The results obtained were of good quality, proving the feasibility of using metaheuristics to manage the inclusion of commercials in the Programming Grid of Digital TV and IPTV.

■ MA-50

Monday, 8:30-10:00 - Graham Hills GH512, Level 5

Efficiency Evaluation Measurement in Container Ports

Stream: Container Terminals
Invited session
Chair: *Pasquale Legato*
Chair: *Sanja Bojic*

1 - US East Coast Ports: A Comparative Evaluation of Infrastructure

Joyendu Bhadury, Torupallab Ghoshal

This talk focuses on the current state of preparedness of ports in East Coast of USA a framework for the Post-Panamax era in shipping. It will begin by reviewing current literature available on the expansion of the Panama Canal and its impact on the size of ships as well as shipping flows in and out of US ports. This will include a review from published accounts of current infrastructure projects in place to upgrade existing

port facilities on the East Coast of USA. A structured framework will be introduced to compare these ports, based on attributes including current operational capacity of the port as measured in annual number of TEUs transacted; current depth of navigational channel; distance from open water; current port infrastructure especially availability and capacity of cranes; supporting highway structure; access to railways and/or intermodal facilities; available land for future development and the current number of ocean carriers calling at the port. This framework will be used to illustrate where each port ranks per attribute. Thereafter, a ranking scheme will be introduced on the basis of these attributes that attempts to measure the preparedness of each port for Post-Panamax container vessels. This ranking scheme will also take into account the infrastructure improvement projects currently in place to upgrade these ports on one or more of the attributes above and their expected completion dates.

2 - Evaluation of Operational Efficiency for Brazilian Port Terminals Specialized in Container Cargo Using Multiple Criteria Data Envelopment Analysis

Ana Paula dos Santos Rubem, Luana Carneiro Brandão, Eduardo Costa, Lidia Angulo-Meza, João Carlos Soares de Mello

This work examines Brazilian port units specialized in the exclusive operation of container cargo during 2013. For that, we use a model that combines Data Envelopment Analysis (DEA) and Multi-Objective Linear Programming, known as Multiple Criteria Data Envelopment Analysis (MCDEA). We develop an output-oriented MCDEA model, once the original input-oriented model is not suitable for the problem under consideration. From the non-dominated solutions, we calculate a MCDEA-based measure of efficiency, which revealed our approach managed to slightly improve the discrimination of classic DEA, reducing the efficiency of Porto Itapoá from 100% to 97%, while Chibatão and Portonave remained 100% efficient, and Embraport maintained its score of 39%. However, the MCDEA optimization resulted in null weights for the input "maximum draft' of every unit. As it is expected that all input and output values assigned to the unit under evaluation be taken into account when computing the final score, we propose an alternative process, based on goal programming, for the calculation of non-null weights. The results indicate that, in our case study, to assure non-null weights, it is necessary to worsen at least one value of the objective functions related to a non-dominated solution, thus referring to a MCDEA solution that is not Pareto-efficient. The study also suggests Brazilian container terminals are rather homogeneous, except for Embraport, which had just started handling containers.

3 - Location Problem of Container Terminals - an Internal and External Costs Approach

Sanja Bojic, Dejan Brcanov, Milosav Georgijevic, Nenad Zrnic

In the situation of permanently growing demand for container transport and handling services, enabling further development of economy without harming the environment become one of the biggest challenge. Locating container terminal while minimizing both transport costs and environmental effects can make significant long term sustainable influence both on economy and environment. Within this paper, a bi-objective mathematical model for the location problem of container terminals on the existing transportation network is developed. The model enables determination of optimal number, capacity and location of container terminals, as well as the allocation of the customer demand to the located terminals, by satisfying two defined objectives: minimization of internal transport costs and minimization of external transport costs (costs related to the CO2 emissions and noise). Thereat, as the possible container terminal locations are considered the continental intermodal network nodes that are recognized as the hinterland connections of the sea ports. The effectiveness of the proposed approach is evaluated with a numerical example of locating container terminals in the Republic of Serbia.

4 - The Vehicle Round Trip Model Addressed by an Analytical Queuing Network

Pasquale Legato, Rina Mary Mazza

Maritime container terminals have received great attention from the OR-Simulation communityin the attempt toanalyze and optimize resource allocation policies and activity scheduling rulesunder uncertainty.Discrete-event simulationmodels, which are particularly fit to reproduce complex features within specific subsystems, may be combined with queuing network models to provide average performance metrics of the system as a whole. Herea queuing model and an analytical solutionis proposed for the vehicle round trip process:containers are picked-up from one subsystem and set down in another by man-guided straddle carriers (SCs) that travel back and forth between the quay-stationsand the yard-stations. Under the assumption that the fleet of circulating SCs corresponds to the customer population, a closed queuing network model for the vehicle round trip processarises. The suitability and effectiveness of using analytical queuing approximations to get reliable results on quantitative performance metrics such as terminal throughput and vessel sojourn time is investigated. Numerical experiments are carried out with respect to a container terminal of pure transshipment. Discussion of some encouraging results, as well as other less encouraging ones, provides some guidelines on future development and/or suitable adaption to container terminal logistics of the large body of techniques and algorithms available nowadays.

■ MA-52

Monday, 8:30-10:00 - Graham Hills GH554, Level 5

Financial Mathematics 1

Stream: Financial Mathematics and OR
Invited session
Chair: *Norio Hibiki*

1 - The portfolio evaluation of the Japanese pension fund

Masanori Ozawa, Tadashi Uratani

In Japan, the population is decreasing about 400 thousand people per year and the number of pensioners is increasing about 700 thousand people per year. The government has reported actuarial valuation of the pension systems every fifth years since 2004. In these reports, the key factors of pension evaluation were macroeconomics scenarios and fertility scenarios. Recently, Government pension investment fund (GPIF) has announced the change of basic portfolio. The portfolio weight to foreign stocks is increased significantly. Then we consider the risk management under the global economic vulnerability. Our simulation model for Japanese pension systems is based on premium, benefit, government subsidy, and the portfolio management. We study the probability of default of pension fund under various scenarios and portfolios using the simulation model.

2 - Free boundary problem for double exercise Asian option

Tomatsu Takumi, Katsunori Ano

We study the double exercise Asian option. For two times exercise chances, the system of the corresponding free-boundary problem (FBP) are derived and the optimal stopping strategy are studied in details. We present the proofs for the main components in the free-boundary problem such as the smooth-fit condition. The verification theorem of the FBP for the pair of the optimal price and the optimal stopping boundaries are proved.

3 - Longevity assets and pre-retirement consumption/portfolio decisions

Francesco Menoncin

We derive a closed form solution for the optimal consumption/investment problem of an agent whose force of mortality is stochastic and whose financial horizon coincides with a fixed retirement date. The complete financial market allows for investment in a risky asset, a zero-coupon bond and a longevity asset, which we model as a zero-coupon longevity bond. We explore the optimal demand for these assets by a representative agent having Hyperbolic Absolute Risk Aversion preferences on both consumption and final wealth. Our numerical analysis shows that individuals should optimally invest a large fraction of their wealth in the longevity asset, unless its risk premium is (excessively) unattractive. In our base scenario, calibrated on real world data, a 60-year old male retiring after 5 years should invest around 88% of his wealth in the longevity asset. Such a percentage decreases as time to retirement decreases. We explore sensitivity of our results to market and individual characteristics.

4 - Optimal Pair Trading Strategy for Actual Fund Management using Derivative Free Optimization
Rei Yamamoto, Norio Hibiki

We discuss the optimal pair trading strategy that can be conducted in the actual fund management situation. First we generate the simulation paths of the pair of asset prices which follow the stochastic process used in many theoretical researches. We define the evaluation function associated with trading cost, risk and expected return that is used in the standard practical researches. Finally we formulate the optimal pair trading strategy based on the standard trading rule in the discrete-time setting and solve the problem using derivative free optimization (DFO) method. We show the optimal pair trading strategy in the computational analysis under various pair parameters such as convergence speed, volatility and correlation. In our research, we find the difference of the optimal pair trading strategy between our practical fund management setting and the theoretical setting based on the previous researches.

■ MA-53

Monday, 8:30-10:00 - Graham Hills GH614, Level 6

Stochastic Optimal Stopping

Stream: Dynamical Systems and Mathematical Modelling in OR
Invited session
Chair: *Krzysztof Szajowski*
Chair: *Aiko Kurushima*

1 - No-arbitrage machine learning models for pricing American options
Huisu Jang, Youngdoo Son, Hyunwoong Ji, Jaewook Lee

Recently, machine learning models have been widely studied to pricing financial derivatives and have shown to give a better prediction accuracy than that of parametric stochastic volatility or jump models However, most of them suffer from arbitrage opportunities when they are applied to pricing real options whose variables are extrapolated, leading to serious mispricing when option market makers are going to implement them. In the present study, we propose a method to implement machine learning models satisfying no-arbitrage constraints for American options. We also conduct a comprehensive study to verify the predictive performance of the proposed no-arbitrage machine learning models compared to other non-parametric and parametric models by applying them to one year S&P 100 daily American put options.

2 - Optimal stopping strategy for Odds problem with uniformly distributed number of items
Aiko Kurushima, Katsunori Ano

This paper studies an Odds problem, that is one of frontier of the optimal stopping fields,with uniformly distributed random number of items. The problem is described as follows: the number of the trials is the random variable, whose probability distribution is known and uniform. Let X_1, X_2,... denote independent 0/1 random variables. We observe these X_i's sequentially and we call i-th trial success if $X_i=1$. Let p_i denote the probability of success for i-th trial, that is, $P(X_i=1)=p_i$. Also set $q_i=1-p_i$ and the "odd," $r_i=p_i/q_i$. The objective is to maximize the probability of selecting the last success. We also generalize the problem with multiple selections.

We present the sufficient condition on the probability distribution of the number of trials for the optimal stopping rule, and examine the optimal stopping rule and maximum probability of win for single stopping and double stopping.

3 - Duration problem for nonextremal observations
Marek Skarupski, Krzysztof Szajowski

Duration problem was considered by Ferguson, Hardwick and Tamaki (1992). It was the first paper that considered this type of problem. Idea was extended by Pearce, Szajowski and Tamaki (2012) where the multiple choice duration problem was considered. In this talk we consider a modification of classical duration problem which we call a duration problem for nonextremal observations. We consider different strategies and show which one is optimal.

4 - Stopping problem for partial information geometric random walk
Katsunori Ano

This paper studies Bayesian stopping problem to maximize the expected reward on the geometric random walk with unknown upward probability. The prior distribution of the upward probability is assumed to be a Beta with two parameters, and it is updated by Bayesian manner based on the past information of the number of upward. It may be interesting that the parameters of the Beta distribution are regarded as an investors' future view for the underlying geometric random walk. We discuss when the optimal stopping time is a threshold type, that is, the first hitting time to some boundary.

■ MA-54

Monday, 8:30-10:00 - Graham Hills GH617, Level 6

Management Accounting and Control 1

Stream: Experimental Perspectives and Challenges in Management Accounting and Management Control
Invited session
Chair: *Andrej Bregar*

1 - Knowledge — Based Models in the Marketing Decision Making under Conditions of Uncertainty
Otilija Sedlak, Zoran Ciric, Tibor Kis, Marija Cileg

The main goal of this paper was to present the knowledge based model that will provide more successful and efficient decision making in the area of marketing, in relation with dilemma "to produce or to buy', because the make-or-buy methodology is one of the most critical strategic decisions within logistics outsourcing and should be taken in a structured and consistent manner. Authors tried to develop a model that will be suitable for making marketing decisions in production systems. Methodology in the paper obtained analysis of the theory of marketing and knowledge based systems, the development of the specific model for decision making. The research problem in this paper was proposed in terms of model development. Authors developed model for decision making, based on successful integration of marketing and knowledge based theories. Also, this was proposed as universal model which can be implemented in each production system. Authors analyzed the main theoretical developments in the area of marketing and decision making and knowledge based systems. They presented the model and specific decision making problem that has been solved by developed model. At the end, authors pointed the advantages of the model but also some limitations and possibilities for the future researches.

2 - Pricing When Customers Have Limited Attention
Yalcin Akcay, Tamer Boyaci

We study the optimal pricing problem of a firm facing customers with limited attention and capability to process information about the value (quality) of the offered products. Based on the theory of rational inattention in the economics literature, we model customer choice as a generalized multinomial logit model, which captures the intricate effects of customer's prior beliefs and cost of information. We formulate the firm's price optimization problem and show the concavity of the revenue function in choice probabilities for both monopolistic and competitive settings. Our comprehensive analytical results and extensive numerical experiments illustrate the impact of fundamental problem features such as the cost of information acquisition and processing, customer's prior beliefs, and the quality levels of the products on prices and profitability. We show that using alternative pricing policies that ignore the limited attention of customers can potentially lead to significant profit losses for the firm. We also discuss the managerial implications of our key findings and prescribe insights regarding information provision and product positioning.

3 - Algorithms to maintain and direct the decision-making group: analysis of their influence on the user-perceivable complexity of the decision-making process
Andrej Bregar

Within the scope of past research work, we have proposed a general framework for the evaluation of decision-making methods, processes and systems, which focuses on the aspects of analysis, group maintenance and methodological foundations. On its basis, we have also introduced a specialized framework for the measurement and reduction of user-perceivable complexity of group decision-making methods, processes and systems. Because of its broad scope, the previous research has been limited to a general definition of low level factors and informal identification of correlations between groups of these factors. In this presentation, we delve deeper into correlations between factors, in order to define and justify them in a more formal, rigorous and in-depth manner. We focus primarily on factors that refer to the ability to maintain and direct the process of group decision-making. We observe and analyse the influence of these factors on other complexity factors, such as decision accuracy, validity of results, focus on problem solving, thoroughness of analysis, communication efficiency, cognitive load during the process of decision-making, complexity and richness of preferential information, robustness, etc. We investigate the strengths of correlations by means of a case study, an experimental simulation study, bivariate statistics and qualitative research. We base the research on the characteristics of autonomous algorithms to maintain and direct the decision-making group.

■ MA-55

Monday, 8:30-10:00 - Graham Hills GH626, Level 6

Energy and Power Systems and Related Subjects

Stream: Data Mining in Finance and Commodities
Invited session
Chair: *Johanna Marcela Orozco Castañeda*
Chair: *Marcus Hildmann*
Chair: *Dejan Stokic*

1 - Congestion Management through Topological Corrections: A Case Study of Central Western Europe
Jinil Han, Anthony Papavasiliou

The integration of increasing amount of renewable generation within Europe is posing operational challenges that require various balancing actions. System operators therefore need to rely increasingly on the active control of the transmission network. Transmission topology control is a fast and economic option to add flexibility to the transmission system. We model the current methodology for controlling congestion in the Central Western European (CWE) market and quantify the benefits of topology control. We also compare the results with a nodal pricing model. Our computational results suggest that topology control can significantly reduce congestion management costs under the current market coupling regime whereas the benefits of topology control are limited under the nodal pricing. Topology control emerges as an attractive and implementable means of managing congestion as it provides a significant percentage of the cost savings that would be achieved by overhauling the existing European market design and shifting to a nodal pricing regime.

2 - Forecasting electricity price spikes with Support Vector Machines
Efthymios Stathakis, Theophilos Papadimitriou, Periklis Gogas

In this paper, we use high-frequency data from the German EPEXSpot electricity market and develop a model to forecast the occurrence of positive and negative spikes in the hourly electricity prices. Price spikes are extreme movements in price levels caused by unexpected imbalances in the demand or supply. To identify these extreme movements we employ an AR-GARCH model as a pre-filtering method to eliminate time-dependency and heteroskedasticity in price-series. Then, we use a certain high threshold above which the exceedances follow the Generalized Pareto distribution. Through this method we detect 2620 price spikes, negative and positive, in total of 13202 observations. To forecast these price spikes we employ a multiclass Support Vector Machines (M-SVM) model. Although this was originally developed for binary classification, SVMs can be extended to deal with multiclass classification problems. Using one-against-one method the multiclass problem is degenerated into $k(k-1)/2$ binary classifiers, with k classes. The accuracy measure we use to evaluate the in-sample and

out-of-sample performance is an F1 Score. In order to develop a consistent forecast model we use an augmented rolling window for the in-sample data while the out-of-sample window is fixed. In every step the in-sample set is augmented by a set of observations equal to the out-of-sample set. The F1 Score of our model ranges between 54% and 65% for the period from January 1, 2014 to June 30, 2014.

3 - Nonlinear Forecast Encompassing with Artificial Neural Networks
Johanna Marcela Orozco Castañeda, Eduardo Alonso, Lilian De Menezes, Juan David Velásquez Henao

Artificial Neural Networks (ANN) are considered to be well suited to the problem of nonlinear forecasting due to their flexibility and capability to approximate any measurable function to any accuracy, given sufficiently many hidden units. In particular, recent results on forecasting (e.g., stock index prices) have shown that the performance of ANN in volatility prediction is slightly superior in relation to those of GARCH models. In the context of time series forecast combination, knowing how to establish the contribution of each individual forecast is paramount to reduce the prediction error and to determine whether competing forecasts can be effectively combined. In the linear forecast combination approach, forecast encompassing hypothesis tests are conventionally used to define and test if one forecast in the combination is encompassed by the competing forecasts. On the other hand, in the nonlinear forecast combination, there is a lack of definition and tests for forecast encompassing. In this paper, we extend the definition of linear forecast encompassing for the nonlinear case, and use a Regression Neural Network (RNN) as a method for combining forecasts, where the input variables are different forecasts of a same variable. A Wald-statistic test is then used to test the significance of the parameters of each forecast as an input variable in the RNN. Hence, the potential contribution of each competing forecast is assessed in a nonlinear framework.

■ MA-60

Monday, 8:30-10:00 - Graham Hills GH813, Level 8

Applications of Vehicle Routing

Stream: Routing I - Models and Methods
Invited session
Chair: *Simona Mancini*

1 - The Vehicle Routing Problem with limited traffic zones and electric vehicles
Simona Mancini

In this work a new Vehicle Routing Problem is introduced and formalized. This problem consists into visiting a set of customers, starting from a given depot, with a fleet composed by two categories of vehicles, traditional (TVs) and electric (EVs) ones. A maximum number of vehicles for each category is imposed. Route length limitations hold for electric vehicles due to their small battery capacity, while no length restrictions are applied to routes performed by TVs. A maximum route duration is imposed for every route. EVs can visit every customer at any time, while TVs must respect a time window within which access to some customers is forbidden. EVs and TVs have different kilometric cost (much higher for TVs). The objective is to minimize the total routing cost, while visiting all the customers and respecting all the constraints. In this talk a mathematical formulation and a heuristic algorithm are proposed. The heuristic is a Large Neighborhood Search Matheuristic in which the neighborhood search is exploited directly by the model which is able to exhaustively explore even large neighborhoods in a very short computational time. The proposed approach is high performing and extremely flexible. In fact, different neighborhood structures may be considered and this method may be easily embedded in a more complex metaheuristic framework such as Adaptive Large Neighborhood Search (ALNS) or Variable Neighborhood Search (VNS).

2 - Maximizing user benefits by changes in incomplete networks
Corrinne Luteyn, Reginald Dewil, Pieter Vansteenwegen

In this research, a number of Vehicle Routing Problems, in which only a subset of the customers has a demand, are considered in an incomplete network. We have investigated what would be the best improvement of this incomplete network, such that the total travel time of the

vehicles in these routing problems is minimized. Three possible improvements are individually studied in this research: the possibility to add an extra road to the network, to widen one of the existing roads or to convert an existing road into a one-way road with a higher speed. For each improvement, a Mixed Integer Programming formulation is presented to determine the best improvement. Due to the complexity of the problem, a heuristic is introduced to find good solutions in more realistic cases. This heuristic consists of two parts, a construction part and an analysis part. During the construction part, routes for the vehicles are constructed in the current network using a Variable Neighborhood Search. In the second part of the heuristic, the constructed routes are analyzed to determine a good improvement of the network. A case study with a set of scenarios with a different number of customers and a different number of vehicles is executed. The results show that a reduction in total travel time of the vehicles of about 2% can be obtained by improving the network. However, the total travel time in the heuristically improved network is only about 0.16% larger than in the optimally improved network.

3 - Modelling of a real fixed routes problem as a vehicle routing considering multiple time windows and variable arc velocities
Giuseppe Stecca, Simona Di Giampaolo, Marcello Fabiano

Vehicle routing have several and different applications which involve distribution of goods and implementation of services. This work describes an application of vehicle routing to the design of fixed routes. Design of fixed routes has many applications especially in the planning of repetitive delivery or design ship itineraries. The studied case has a set of interesting requirements such as a fixed number of vehicles to be used, not mandatory visit of all nodes, multiple time windows, specific time constraints, variable arc velocity. The paper presents the mathematical formulation and insights about on field solution experience. In particular, velocities and time constraints are modelled in order to guarantee special request of the user such as the ability to force special duration of routes. The mathematical model is implemented in OPL and solved with CPLEX. It was compared with alternative formulations based on temporized network flow model. Complexity and sensitivity analysis shown the effectiveness of the approach. Due the exponential dimension of the problem, the test run shown the importance to select the right preprocessing and approximation strategies, such as the reduction of the number of vehicle's selectable velocities with the consequent restriction of the feasible set.

■ MA-61
Monday, 8:30-10:00 - Graham Hills GH816, Level 8

Dynamic Programming 1

Stream: Dynamic Programming
Invited session
Chair: *Lidija Zadnik Stirn*

1 - Assembly Flow Shop Scheduling: Some New Results
Uttarayan Bagchi

We consider two- and three-stage assembly flow shops where the scheduling objective is to minimize makespan. The first stage contains parallel non-identical resources whereas both the second and third stages contain a single resource. Thus the flow shop can be viewed as consisting of a fabrication stage followed by an assembly stage followed by a final testing stage. We present results on dominance conditions, permutation schedules, and heuristic performance.

2 - A Queueing Model Arising from Managing Small Projects under Uncertainties
Christopher Tang

We consider a situation in which a home improvement project contractor has a team of regular crew members who receives compensation even when they are idle. Because projects arrivals are uncertain and the completion time of each project is also uncertain, it is common for a contractor to accept multiple projects. However, this approach has a major drawback because it essentially causes "intentional" (or foreseeable) project delays. Intentional project delays can inflict explicit and implicit costs on the contractor when some frustrating customers abandon their projects and/or file complaints or lawsuits. In this paper, we present a queueing model to capture uncertain customer (or project)

arrivals and departures, along with the possibility of customer abandonment. Also, associated with each admission policy (i.e., the maximum number of projects that the contractor will accept), we model the underlying tradeoff between accepting too many projects (that can increase customer dissatisfaction) and accepting too few projects (that can reduce crew utilization). By using the steady-state analysis, we examine this tradeoff analytically and we determine the optimal admission policy and the optimal number of crew members. We find that these optimal policies are non-monotone in terms of customer arrival rate. Therefore, a careful selected policy is key.

3 - A Chance Constraint based Approach for Dynamic Vendor Selection Problem with Distinctive Price Breaks under time varying Stochastic data
Remica Aggarwal

In this paper, the problem of vendor selection and purchase order sizing for a single item is considered under dynamic demand conditions and uncertainties related to operational risks such as random or uncertain costs, demands of the buyer, capacity of vendors and the lead time. This is further integrated with the incremental quantity discounts on lot sizes offer by various vendors which may vary over time. The resulting Integrated Dynamic Vendor Selection Problem (IDVSP) under time varying stochastic data is modeled using Chance Constraint approach. The IDVSP is solved using both Non Preemptive Goal Programming and Weighted Aggregate Function technique. To validate the proposed model, data is generated randomly and solved in LINGO 10. The model is demonstrated with an illustrative example.

■ MA-62
Monday, 8:30-10:00 - Livingstone LT203, Level 2

Operations Research 1

Stream: Operations Research, other
Contributed session
Chair: *Adriana Cherri*

1 - Cutting stock problem with stock/sell of retails
Adriana Cherri, Douglas Nogueira do Nascimento, Karen Coelho, Edmea Cássia Baptista

The one-dimensional cutting stock problem with stock/sell of retails differs from the classical cutting stock problem (CSP) by retaining stock retails, with quantities and length previously defined, which can be cut in the future to meet new demands or, if it is attractive, can be sold as an object for other companies to meet their demands. A mathematical model recently proposed in the literature was modified to solve this problem. With this model, we try to capture a usual strategy of many companies which work with the cutting process. Computational experiments were performed with randomly generated instances and presented good solutions.

2 - Expected Commodity Returns and Pricing Models
Gonzalo Cortazar, Ivo Kovacevic, Eduardo Schwartz

Stochastic models of commodity prices, in addition to providing the risk neutral distribution of future spot prices, also provide their true distribution. While the parameters of the risk neutral distribution are estimated more precisely and are usually statistically significant, some of the parameters of the true distribution are typically measured with large errors and are statistically insignificant. In this paper we argue that to increase the reliability of commodity pricing models, and therefore their use by practitioners, some of their parameters —in particular the risk premiums parameters- should be obtained from other sources and we show that this can be done without losing any precision in the pricing of futures contracts. We show how the risk premium parameters can be obtained from estimations of expected futures returns and provide alternative procedures for estimating these expected futures returns.

3 - Obesity and Overweight Control in Mexico: A Systemic Didactic Model
Francisco Aceves

México has an important obesity and overweight problem which is causing an alarming increment of its morbidity and mortality index. To solve this problem the official health institutions have adopted a

preventive campaign that is good but not sufficiently good. To complement this strategy, in this paper a systemic didactic model is proposed, which is based in four main aspects: 1- Nutrition, 2- Physical activation, 3- Sleep, rest and relaxation, and 4- Mental attitude.

■ MA-66

Monday, 8:30-10:00 - Livingstone LT209, Level 2

Parameterized Combinatorial Optimization

Stream: Optimization
Invited session
Chair: *Gregory Gutin*

1 - An Introduction to Fixed-Parameter Algorithms for the Workflow Satisfiability Problem
Jason Crampton

The problem of workflow satisfiability arises when we wish to allocate authorized users to steps in a workflow, subject to some constraints on the allocation. The workflow satisfiability problem (WSP) has some similarity to constraint satisfaction problems and is, in general, NP-hard. In practical instances of WSP, the number of users is much larger than the number of steps. Taking the number of steps as the small parameter, there exist fixed-parameter tractable (FTP) algorithms for sub-classes of the problem that are of relevance to real-world applications, although WSP remains W[1]-hard, in general. In this talk, we provide an introduction to WSP and recent advances in FPT algorithms for WSP.

2 - A Practically Efficient Fixed Parameter Tractable Algorithm for the Valued Workflow Satisfiability Problem
Daniel Karapetyan, Jason Crampton, Gregory Gutin

We introduce an optimisation version of the workflow satisfiability problem (WSP), which we call Valued WSP. The problem now is to find an assignment of users to the steps in a workflow specification such that the total penalty for breaking constraints and authorisations is minimised. Wang and Li (2010) observed that the number k of steps is usually significantly smaller than the number n of users in the organisation and suggested to use k as the parameter in developing fixed parameter tractable (FPT) algorithms. Then Cohen et al. (2014) showed that, for user-independent constraints, all the solutions can be partitioned into B_k equivalence classes, where B_k is the k'th Bell number, and each equivalence class can be compactly encoded. We demonstrate that an optimal assignment within a given equivalence class of the Valued WSP can be found efficiently. Hence, an FPT algorithm can enumerate all the equivalence classes and for each find an optimal assignment. We improve this approach by using the branch and bound technique and applying a robust branching mechanism. We also propose a mixed integer programming (MIP) formulation for the problem and show that our branch and bound algorithm clearly outperforms MIP, greatly extending the range of problems that can be practically tackled. Another contribution is a new generalisation of authorisations that significantly extends the modelling capability of the problem but still does not affect its worst case complexity.

3 - Parameterizations of Chinese Postman Problem
Gregory Gutin

A problem with parameter k is fixed parameter tractable (fpt) if it can be solved in time f(k)*poly(n), where f is any function in k only and n is the size of the problem. When f is not growing too fast and k is not too large, the corresponding algorithm is efficient.

In the Chinese Postman Problem (CPP), we are given a weighted graph G and we wish to find a closed walk through all edges of G of minimum total weight. It's well-known CPP is polynomial time solvable when G is either directed or undirected graph, but CPP is NP-hard when G is a mixed graph, i.e., has both directed and undirected edges.

We'll discuss the following results for Mixed CPP. If the parameter k is either the number of directed edges or the number of undirected edges, the CPP is fpt. Surprisingly, if k is the treewidth of G then CPP is W[1]-hard, i.e., very unlikely to be fpt. Two of the above results solve open questions by van Bavern, Niedermeier, Sorge, and Weller (Chapter 2 in Corberan and Laporte (eds.), Arc Routing: Problems, Methods and Applications, SIAM, Phil., in press).

■ MA-67

Monday, 8:30-10:00 - Livingstone LT210, Level 2

Models for Energy Optimization

Stream: Combinatorial Optimization
Invited session
Chair: *Chiara Bordin*
Chair: *Daniele Vigo*

1 - Unit Commitment Benchmark Problems
Paula Carroll, Damian Flynn, Alexander Melhorn, Mingsong Li

Unit Commitment (UC) is an optimization problem that determines which generating units be selected and dispatched to meet power demand and satisfy the operating constraints of the generating units and of the system as a whole. Many models and solution approaches have been described in the literature. Competitive market systems, a focus on integrating renewable energy sources, and security and stability issues arising from the interconnection of national and regional systems have driven interest from the community of practitioners for improved UC solution approaches. The 10 unit system described in Kazarlis (1996) is most often used to benchmark UC algorithmic performance. In this work, a realistic standardised benchmark test set and data format based on an Irish case study are described. In particular, test instances that represent the variability of wind power are proposed and the computational impact on a standard UC MIP model assessed. The use of a benchmark test set allows for a more accurate and complete comparison of unit commitment models and algorithms by the research community.

2 - Combined Heat and Power Short-term Production Scheduling and Trading
Ilias Dimoulkas, Mikael Amelin

The short-term production scheduling of combined heat and power plants (CHP) is a challenging task. The need for simultaneous production of heat and power in combination with the technical constraints results in a problem with high complexity. Furthermore, the operation in the electricity markets environment means that trading decisions have to be made before any electricity prices have been established. In order to compensate the increased risk of making decisions under such uncertain conditions, tools like stochastic programming can be used. In this work, the short-term operation scheduling model of a CHP system in the day-ahead and real-time electricity markets is mathematically described and solved. The problem is formulated in a stochastic programming framework where the uncertain parameters of day-ahead / real-time electricity prices and the heat demand are incorporated into the problem in the form of scenarios. A case study is also performed with a CHP system operating in a district heating network.

3 - Optimal Operation of Power Distribution Networks
Maria Teresa Vespucci, Paolo Pisciella, Diana Moneta, Giacomo Viganò

A Distribution System Operator (DSO) will be in charge of operating power distribution networks, in order to compensate generation-load imbalances with respect to a previously determined scheduling, while guaranteeing constraints on currents in lines for security and voltages at nodes for power quality. Internal (i.e. owned by DSO) regulation resources will be electricity storage devices and on-load tap changers. DSO's external regulation resources (i.e. owned by third parties) will be the dispatch of active and reactive power of generation plants and the exchange of active and reactive power with the high voltage transmission network. Costs associated to the use of internal regulation resources reflect device deterioration; costs associated to the use of external regulation resources are to be defined by the Regulator, so as to allow a technically efficient operation of the network. The optimal redispatch minimizes the total costs for using internal and external resources, constrained by power flow equations, balance equation for the batteries and local control constraints. Active losses are also considered and penalized in the objective function. The problem is modeled by using a non linear sparse formulation and solved using a primal-dual interior point method. The procedure allows finding efficient configurations of the network and can be used as a simulation tool by the Regulator to analyze the impact of different costs associated to external regulation resources.

4 - A Linear Programming Approach for Optimal Battery Operation in Off-Grid Solar Power Schemes, with Consideration of Battery Degradation
Chiara Bordin, Oghenetejiri Harold Anuta, Andrew Crossland, Isabel Lascurain Gutierrez, Chris Dent, Daniele Vigo

Storage technologies and storage integration are currently key topics of research in energy systems, due to the resulting possibilities for reducing the costs of renewables integration.

Off-grid power systems in particular have received wide attention around the world, as they allow electricity access in remote rural areas at lower costs than grid extension. They are usually integrated with storage units, especially batteries. A key issue in cost effectiveness of such systems is battery degradation as the battery is charged and discharged.

We present linear programming models that can be used to optimise management of off-grid systems. The key contribution of this work is the inclusion of battery degradation costs in the optimisation models. As available data on relating degradation costs to the nature of charge/discharge cycles are limited, we concentrate on investigating the sensitivity of operational patterns to the degradation cost structure. The objective is to investigate the combination of battery costs and performance at which such systems become economic. We also investigate how the system design should change when battery degradation is taken into account.

■ MA-69

Monday, 8:30-10:00 - Livingstone LT212, Level 2

Business-driven Data Mining 1

Stream: Business Analytics and Intelligent Optimization
Invited session
Chair: *Alex Seret*

1 - Application of a personalized collaborative filtering job recommender system for the Flemish employment service
Michael Reusens, Alex Seret, Bart Baesens, Wilfried Lemahieu, Luc Sels

Recommending vacancies to job seekers is a crucial part of an employment services' task to link supply and demand on the labor market. Knowledge based recommender systems based on user- and vacancy profiles are often applied in this context because of their high scrutability and safe recommendations. They do however require a large amount of knowledge engineering to set up. On top of this, our preliminary experiments show that there is often a mismatch between the type of jobs people explicitly indicate to be interested in, and the jobs the user's implicit feedback indicates an interest for. This causes recommendations coming from a knowledge based recommender system not always to be aligned with a user's interest. In this paper we propose and evaluate a collaborative filtering job recommender system based on implicit user feedback. Existing research shows that collaborative filtering recommender systems suffer from a cold-start problem and small neighborhoods of similar people in case of high sparseness, both of which also manifest themselves in our research. Besides these known challenges linked to collaborative filtering, we identify and propose solutions to new challenges that arise when collaborative filtering recommender systems are applied to job recommendation. The last part of this paper compares our collaborative filtering technique with the knowledge based recommender system as currently used by the Flemish employment services.

2 - Holistically measuring user engagement of digital newspapers to construct a quantitative definition
Klaas Nelissen, Bart Baesens, Monique Snoeck

User engagement is the application-specific emotional, cognitive and behavioral quality of a user experience that goes beyond usability. To better understand user engagement for a specific application, it should be measured holistically, taking into account both the cognitive and behavioral as well as the affective aspect. However, previous work has not adopted this holistic view. This has led to a lack of a practically

applicable quantitative definition of user engagement. In this paper user engagement is measured holistically and a quantitative definition of user engagement is developed specifically for the context of users reading digital newspapers on tablets. Experiments are set up with 60 news readers. Data from multiple sources is collected and compared: all possible interactions of a user with a tablet are tracked, biometric sensors including eye-tracking, ECG, EEG and skin conductance are used, and user surveys are employed. By analyzing the tablet interaction data, the most important features which are indicative of user engagement are identified. This allows us to develop a quantitative definition of user engagement. In conclusion, this project, by closely examining user engagement in the context of digital newspaper readers on tablets, sheds light on the most important features of the newly developed definition of user engagement.

3 - Multi-Criteria-Optimized Rule Extraction For Artificial Neural Networks and Its Application To Customer Scoring
Koen W. De Bock

Neural networks and neural network ensembles have a proven track record in predictive customer analytics. Despite strong predictive performance, high model complexity compromises model comprehensibility and consequently, transportability and acceptance. Rule extraction (RE) techniques are designed to remedy this, resulting in a meta-model that mimics the original model closely, yet is simple in nature and more comprehensible. A well-accepted evaluation framework for RE techniques is the FACC framework: extracted models should envision fidelity, accuracy, comprehensibility and consistency. In this study, NSGA-II is deployed as a meta-heuristic in a rule ensemble framework to produce rule extraction models optimizing and balancing multiple criteria simultaneously. Experiments conducted on multiple datasets in customer scoring benchmark the proposed technique to well-established RE techniques and illustrate it merits.

4 - AnVIM: a Methodology for Creating Business Value with Business Analytics
Giles Hindle, Richard Vidgen

Organisations are exploring how to get value from analytics to transform their organisations and business models. Being good at analytics and predictive modelling is not enough unless it is accompanied by an understanding of the business model, the sources of value, and the opportunities for transformation. To meet this need the Analytics Value Innovation Methodology (AnVIM) has been developed through iterative application in practice. AnVIM draws on the soft systems methodology for business model mapping and value identification. Analysis of the business model is used to identify opportunities for analytics, which are classified in a matrix according to potential for value creation and viability. Those opportunities that are high in value and viability are the focus for analytics development. Analytics models are the pivotal point between business value and data; they are the means through which data is made into information. The scope of AnVIM further includes an assessment of data availability and quality. However, rather than drive the analytics process bottom-up from data or top-down from the business model and value sources, AnVIM argues that both are needed, i.e., an ambidextrous ability to explore (e.g., to find new opportunities and patterns in the data) and to exploit (e.g., to drive analytics models from known business issues and opportunities). The AnVIM approach is illustrated through vignettes in the food bank and telecommunications industries.

■ MA-70

Monday, 8:30-10:00 - Livingstone LT303, Level 3

Hyper-heuristics and Evolutionary Learning

Stream: Data Science for Optimisation
Invited session
Chair: *Daniel Karapetyan*

1 - A Simple Clustering Hyperheuristic Framework for Partitioning of Danish Railway System
Shahrzad Mohammadpour

Danish railways, like any railway system, need to plan for a substantial amount of preventive maintenance tasks. Since the cost associated with such maintenance is expensive, it is significant to reduce the maintenance cost through better planning. To do the maintenance planning in Jutland, the largest area in Denmark, we suggest that the area needs to be divided into subregions prior to the scheduling phase, considering the tasks and crew locations. In order to do partitioning, we propose a clustering hyperheuristic framework dealing with complete solutions generated separately. We define five neighborhood sets of low level heuristics. At each iteration, the framework improves the cluster(s) by switching between the low-level heuristics randomly to push the solution to the desired solution space. The framework is tested upon twelve geographical datasets in the Danish railway network. The results indicate that the framework can improve the initial results theoretically, and can also be used practically as a region splitter for the Danish railway system. Finally, to assess the cohesion of the clustering results to be used in scheduling phase, the validity factor of compactness was measured, and which resulted in significant improvement by the presented framework.

2 - Moving Towards Big Data Scalability with the Grammatical Evolution System
Miguel Nicolau

Evolutionary Computation techniques in general, and Genetic Programming (GP) type systems in particular, are symbolic combination search algorithms, often used in regression problems. The solutions these systems provide are often competitive when compared to similar learning systems, and, being in symbolic form, have the potential to provide insight into relationships between predictors, and estimate the overall complexity of resulting models. With the advent of big data, and the increasing need for effective modelling, GP-like systems provide several advantages. These systems present a highly parallelisable structure, where each member of a population of semi-independent solution candidates is individually applied to a set of training samples. The increasing presence of connected computing devices presents a formidable opportunity for the scalability of GP-like systems. In this work, we propose and partially implement a framework to deploy one such system, Grammatical Evolution, across a highly heterogeneous, asynchronous network of computing devices. We work towards a system combining the dynamic nature of such a network with the inherent adaptability of evolutionary systems. Early experiments are designed, using the open-source million song dataset.

3 - Issues in Interfaces for Applying Data Science to Optimisation
Andrew J. Parkes, Ender Özcan, Daniel Karapetyan

We discuss the latest progress in extending the HyFlex interface (www.hyflex.org) and framework. In particular, we show how the exchange of information, between domain level solver and a hyperheuristic, can be made more flexible but without losing the domain independence. This will give a rich and structured stream of information from the domain solver, but doing so in a fashion that is amenable to the flexible application of data science techniques. Hence, hyperheuristics, and the HyFlex framework, can be expected to provide a rich set of future challenges for machine learning.

■ MA-71
Monday, 8:30-10:00 - Livingstone LT307, Level 3

Behavioral topics in RM

Stream: Revenue Management
Invited session
Chair: *Anton Ovchinnikov*

1 - Behavioral Anomalies in Consumer Wait-or-Buy Decisions
Manel Baucells, Nikolay Osadchiy, Anton Ovchinnikov

A decision to buy an item at a regular price or wait for a possible markdown involves a multi-dimensional trade-off between the value of the item, the delay in getting an item, the likelihood of getting it and the magnitude of the price discount. Such trade-offs are prone to behavioral anomalies/regularities by which human decision makers deviate from the discounted expected utility model, the benchmark adopted in the existing markdown management literature. In this paper

we build an axiomatic framework that accounts for three well-known anomalies, and produces a parsimonious generalization of discounted expected utility. We consider a Stackelberg-Nash game between a firm that decides the markdown discount and a continuum of consumers who decide to wait or buy, anticipating other consumers' decisions and the resultant likelihood of product availability that emerge in the equilibrium. We solve the markdown management problem analytically, and contrast the results of our model to those under the discounted expected utility. Finally, we elicit the realistic values of model parameters by means of a laboratory experiment. We show that accounting for the behavioral anomalies results in substantially larger markdowns than the current literature suggests, and leads to noticeable revenue gains.

2 - Revenue Models for Off-grid Energy
Ioana Popescu, Bhavani Shanker Uppari, Serguei Netessine

One quarter of the world does not have access to electricity, with poor households spending up to half their income on kerosene. Alternative solar technologies are healthier and offer greater value, yet require significant one-time investments which are unaffordable to people living on $2/day. We explore innovative business models for serving this market, including a case study in Rwanda.

3 - Strategic consumers, Revenue Management, and the Design of Loyalty Programs
Anton Ovchinnikov, So Yeon Chun

We study an interaction between revenue management and premium-status loyalty program (e.g., "Gold' status with an airline or hotel), and the role strategic consumers play in this interaction. Specifically, we consider a change occurring in early 2015 when several major airlines announced a switch from a mileage-based loyalty programs (under which consumers obtain the Gold status by flying a certain number of miles) toward "spending-based' programs (under which consumers obtain the Gold status by spending a certain number of dollars). This change has been met with a fierce opposition from media and consumers.

We present a novel model of how forward-looking and status-seeking strategic consumers decide on how much to purchase/fly over a certain time-period in response to the firm's prices, loyalty program design and Gold qualification requirements. We then incorporate this response into the firm's pricing and loyalty program design problem.

We show that the firm can benefit from strategic consumer behaviour if it properly coordinates its RM and loyalty activities, and it benefits more under the spending-based design. Some consumers, however, may suffer from the spending-based design as compared to the mileage-based. There exist, however, a spending-based design which is Pareto-improving over the optimal mileage-based one. To achieve it the firm may need to sacrifice a portion of its profit to benefit each and every consumer.

■ MA-72
Monday, 8:30-10:00 - Livingstone LT311, Level 3

Boolean and Pseudo-Boolean Optimization

Stream: Boolean and Pseudo-Boolean Optimization
Invited session
Chair: *Endre Boros*

1 - Comparing quadratic reformulations of nonlinear binary optimization problems
Elisabeth Rodriguez-Heck, Yves Crama

We consider the problem of minimizing an unconstrained multilinear polynomial in binary variables. Reductions of this problem to the quadratic case have been proposed by several authors and have recently been shown to be efficient for the solution of large-scale problems. In this talk, we revisit two such approaches proposed, respectively, by Rosenberg (1975) and by Buchheim and Rinaldi (2007). We investigate the relation between these reductions as well as the quality of the bounds that they yield, both from the theoretical and from the computational point of view.

2 - PseudoBoolean models for portfolio selection
Andrea Scozzari, Francesco Cesarone, Fabio Tardella

Starting with the seminal work by Markowitz, a large number of (continuous) optimization models have been proposed to find an ideal allocation of capital among several available assets to achieve the investor's objectives.

Among them, due to known difficulties in obtaining reliable parameter estimates, the recent Risk Parity approach calls for equally sharing the risk among all assets of the market, thus disregarding the utility of the investor. We propose here a new nonlinear PseudoBoolean model that joins the benefits of the Risk Parity approach and of utility maximization, and we propose an efficient heuristic for its solution.

3 - Quadratization of pseudo-Boolean functions
Martin Anthony, Endre Boros, Yves Crama, Aritanan Gruber

A pseudo-Boolean function is a real-valued function of binary variables. For such a function, $f(x)$, we say that $g(x,y)$, a function defined on the same variables as f and some number m of auxiliary binary variables y_i, is a quadratization of f if $g(x,y)$ is a quadratic polynomial such that the minimum value of $g(x,y)$ over all x,y is the same as the minimum value of f over all x. By means of quadratizations, minimization of f is reduced to minimization (over its extended set of variables) of the quadratic function $g(x,y)$. This is of some practical interest because minimization of quadratic functions has been thoroughly studied for the last few decades, and much progress has been made in solving such problems exactly or heuristically. This talk reports on results obtained from a study of the minimum number of auxiliary variables required in a quadratization of an arbitrary function f.

4 - Recent Results on Threshold separability of Boolean Functions
Giovanni Felici, Endre Boros

We consider the conditions for the existence of a Linear Threshold Function that separates two sets of Boolean vectors obtained by the discretization of real valued data. In previous work, a combinatorial necessary and sufficient condition for the existence of such function when points belong to the plane was stated, showing its equivalence with a straight-forward interpretation of the Farkas' Lemma. In this presentation we show a similar necessary and sufficient condition that applies to data points in n-dimensions. This result is of practical interest for the design of fast and effective discretization algorithms in supervised learning.

■ MA-73
Monday, 8:30-10:00 - Collins CL205, Level 2

Supply Chain Forecasting & Information Sharing

Stream: Forecasting & Time Series Prediction
Invited session
Chair: *John Boylan*

1 - Product life cycle forecasting
Nicole Ayiomamitou, Michael Wilson, Andrew Lahy, Aris A. Syntetos

The rapid evolution of technology coupled with an increased market focus on innovative and complex solutions has resulted in a very fast pace of introducing new products that are associated with very short lifecycles. In addition, in certain industries, like the fashion industry for example, such products constitute the norm. Forecasting demand requirements for products with short life cycles and managing the relevant inventories is known to be a particularly difficult task. Mapping the inventory requirements across the product life cycle and being able to describe the transit stages offers the ability to react fast into market changes. In this work, the Bayesian statistical techniques developed by Yelland and Dong, (2014: Forecasting demand for fashion goods: a hierarchical Bayesian approach, in: Intelligent Fashion Forecasting Systems: Models and Applications. Springer, pp. 71—94) are being adapted and used for forecasting demand in the fashion industry. Real data coming from a case organization is utilized to assess the empirical validity and utility of the proposed solutions and interesting insights are offered to practitioners working in this area. This work is part of a Knowledge Transfer Partnership (KTP) conducted in the UK and funded by Innovate UK and the Engineering and Physical Sciences Research Council (EPSRC).

2 - Re-evaluating the bullwhip effect measurement: what are we capturing?
Patrick Saoud, Nikolaos Kourentzes, John Boylan

A major problem that supply chains face is the Bullwhip effect, which manifests itself by an upstream increase in the variability of demand. This phenomenon bears costly implications on the firms in the supply chain, and thus has been at the topic of numerous studies. Even though a vast body of literature has been dedicated to alleviating it, a much smaller effort has been placed in quantifying it. We proposes a new measurement to gauge the bullwhip effect, after highlighting the possible flaws of the current ones. Indeed, establishing adequate measures proves to be crucial in evaluating any contribution to dampen the Bullwhip Effect. The most pervasive metric employed is the ratio of variance, which consists of computing the ratio of variance of order placed over the variance of the demand at each node. Despite its ubiquity, this measure fails to serve its purpose on several occasions, such as in the case of seasonal demand, which is frequently encountered in real life. It also penalizes promotions, which appear as outliers, another driver of the Bullwhip Effect. An additional issue associated with this measurement is the nature of the costs that the metric ought to reflect. The fluctuations of the demand variability does not translate directly into the possible costs that can be incurred, nor does it assess the performance of the supply chain as a whole. This paper will investigate potential caveats and costs of the ratio of variance metric before introducing a new measure.

3 - The perils of sharing information in a trade association under a strategic wholesale price
Noam Shamir

We study the incentives of a group of retailers, organized as a trade association and sourcing the product from a single manufacturer, to exchange private forecast information. We compare two widely-used policies by the trade association in practice: exclusionary information exchange and non-exclusionary information exchange. Under the exclusionary policy, only retailers who contribute their private information are exposed to the pool of shared information, whereas under the non-exclusionary policy, all of the members of the trade association are exposed to the pool of shared information regardless of any contribution to this pool. We show that when the wholesale price is exogenous, the retailers have an incentive to share information under both policies. However, when the manufacturer is aware of the exchange of information among the retailers, she sets the wholesale price more aggressively, even without being exposed to the actual shared information. As a result, under the non-exclusionary policy, no information is shared in equilibrium. Under the exclusionary policy, it is possible to reach a full information-sharing equilibrium, but this equilibrium can make the retailers worse-off compared with the case in which no information is shared. Furthermore, it is also possible for the manufacturer to become worse-off when the retailers share information.

4 - Supply chain forecasting: the customer dimension
John Boylan, Aris Syntetos

A recent study of the 'state of the art' of supply chain forecasting (Syntetos, Babai, Boylan, Kolassa and Nikolopoulos) postulated the following 'dimensions' for supply chain forecasting: i) echelon, ii) location, iii) product and iv) time. It was argued that these distinct dimensions give rise to different modelling challenges. For example, in the time dimension, the issue of temporal aggregation has recently been recognised as being of fundamental importance for supply chain forecasts. In the product dimension, cross-sectional aggregation offers opportunities for improving forecast accuracy in various contexts, such as seasonal forecasting The location dimension may be applied at any echelon of the supply chain. Now that granular data on individual consumer purchases is available in the retail environment, there is an opportunity to examine customer data in much more detail. Traditionally, most supply chain forecasts have been developed using univariate models, but now there is the opportunity to develop multivariate models, at customer level, linked to such factors as discounts, 'points offers' and promised future discounts. This paper will examine the challenges of integrating multivariate models into forecasts for the whole supply chain. This will include an examination of their interaction with the other dimensions of supply chain forecasting, and the issues of cross-sectional and temporal aggregation that arise from their consideration.

■ MA-77

Monday, 8:30-10:00 - Collins Insight Institute

Behavioural OR general papers

Stream: Behavioural Operational Research
Invited session
Chair: *Raimo P. Hämäläinen*

1 - A hitchhiker's guide to putting behaviour change ideas into behavioural OR
Philip Jones

This paper provides a guided tour to the Human Environment Analysis Reasoning Tool (HEART) — a comprehensive internet-based visual knowledge map. It summarises behaviour change ideas from individual to societal perspectives and contains a comprehensive set of analysis resources.

The presentation will take users through a generic process to:

● Understand the human and social environment in a specific context. ● Develop and evaluate desired changes and associated courses of action. ● Make appropriate use of associated theories, methods and models.

Given OR's role to improve the effectiveness of socio-technical systems HEART aims to ensure that practitioners have at least a basic understanding of relevant social science to complement more mathematical OR approaches.

HEART was developed through a NATO research collaboration activity, but is equally applicable to non-military problems.

Bring your laptop and you can try the software.

2 - Model-based organizational decision making: A behavioral lens
Jukka Luoma

Operational research has a long history of improving organizational decision-making practice. However, we have only a limited understanding of model-based decision making in organizations; in particular, whether tools such as optimization, computational modeling and data analytics actually lead to better decision making and, if so, how. Drawing on the behavioral tradition of organizational research, I identify three types of functions for OR in organizations: (i) solve recurring decision problems more effectively or efficiently, (ii) facilitate creative problem solving and (iii) provide feedback about past actions. In general, a method suitable for one of the uses may not fit other purposes as well. Further, all three types of uses for OR imply different criteria for evaluating methods and models. To conclude, I propose some theoretical and methodological avenues for future research in the area of model-based decision-making in organizations.

3 - The impact of consumer behaviour on optimal allocations
Sang-Won Kim

When firms sell the same products at different prices, the demand for any given product class depends on the demand for the other classes. Demand is affected by consumer behaviours e.g. diversion, strategic consumer behaviour. Diversion means situations when consumers buy other classes products if the originally requested item is unavailable. Strategic consumer behaviour is designated for situations when consumers delay a purchase until a time point in the future, and wait in anticipation of reopening of the same items. Consumer behaviour has a considerable profit implication. We develop multi-period inventory allocation decisions and simulation models with efficient computer algorithms to reduce computation time. Our numerical results are compared with those from the expected marginal analysis approach and an exhaustive search.

■ MA-78

Monday, 8:30-10:00 - Architecture AR201, Level 2

Practical Operational Research in Healthcare 1

Stream: Practical Operational Research in Healthcare
Invited session
Chair: *Daniel Chalk*

1 - Building health OR capacity at a not-for-profit health provider in remote rural Sub-Saharan Africa
Andrew Dobson

The speaker will describe current work as an OR analyst in remote rural Uganda with a locally-managed medium-sized not-for-profit health service provider. After spells with them over 3 years, initially focussing on specific areas of fundraising, financial planning and efficiency, the role has broadened into consisting mostly of a multitude of strands of capacity building (via coaching, system development and demonstration), of the organisation and its staff and systems, in a wide variety of areas and analytical activities, across public health, clinical and other medical work. It could all be viewed as health OR aimed at sustainability.

The talk will describe how the work developed into this role, and what the current work consists of, with examples including a review of staffing requirements and productivity across the hospital based around the WHO's 'Workload Indicators for Staffing Needs' method, which has stimulated an interest in a variety of further analytical work.

It will then discuss the possibilities and challenges for the future. The potential for OR skills to help is vast, but the effort is becoming thinly spread. So, there is an important question of what approach to take to maximise impact. Some parts of the answer could involve drawing more on OR work done elsewhere in health, joined-up approaches with others working in health OR, and the potential for this work and its contacts to contribute to extending the OR Pro-Bono initiative internationally.

2 - 'Skin in the Game': Embedding Mathematical Modelling in a Health Board in Wales
John Frankish, Paul Harper, Danny Antebi

The Modelling Unit at Aneurin Bevan University Health Board (ABUHB) was established in January 2013 as a joint venture between Cardiff University and ABUHB. The unit has 4 research associates embedded within an NHS Wales organisation for the first time. The team forms a part of the Aneurin Bevan Continuous Improvement (ABCi) team at the Health Board operating across both the Cardiff University School of Mathematics and the Health Board.

ABUHB is responsible for the commissioning and provision of healthcare for a population of about 600,000 people in South East Wales. ABCi supports teams to improve the safety, quality and efficiency of the services they deliver either to patients directly or to those caring for patients. The Modelling team provides a level of analysis of previously unavailable to the organisation. The team has three core offerings: modelling of services in response to commissions from any part of the organisation; the provision of a teaching programme designed to raise awareness and confidence in the use of modelling; and general 'maths support' helping people with smaller issues in handling and analysing data.

In this talk we will overview the unit, provide some examples of the projects and resulting impact, and discuss benefits, issues and lessons learnt from our experience with an embedded team so far and offer some reflections on the role of modelling within the complex environment of NHS healthcare service provision and improvement.

3 - Modelling care pathways for people with bipolar disorder
Dave Worthington, Shihao Tan, Steve Jones, Fiona Lobban

Bipolar disorder (BD) is a severe, chronic mental illness characterized by two types of recurrent episode, mania and depression, which both drastically affect quality of life and ability to function normally. The estimated lifetime prevalence of BD exceeds 1% of the adult population. In the UK the National Institute for Care Excellence (NICE) provides national guidance and advice to improve health and social care, including clinical guidelines for hundreds of conditions. Members of Lancaster University's Spectrum Centre were involved in developing of the 2014 guidelines for BD, where they recognized the importance and difficulty of estimating the resource requirements of key aspects of the guidelines. A project was therefore undertaken last Summer to investigate the feasibility of creating an OR model to estimate resource requirements for specified populations. It quickly became clear that a fairly simple 'stocks and flows' model would be sufficient to capture the main resource implications, but that there would be significant other challenges: (i) to convert the language of the guidelines into unambiguous patient pathways, (ii) to estimate the resource requirements to deliver guideline care to (say) one patient, and (iii) to use available studies of BD to calibrate the model. This presentation provides an overview of the project, and seeks to discuss its implications for 'joining up' the development of clinical guidelines with their likely resource implications.

4 - Optimising Polypharmacy Prescribing Practice using Agent-Based Simulation
Daniel Chalk

Polypharmacy (the concurrent use of multiple medications) can be problematic, and particularly affects those with multiple comorbidities. Polypharmacy increases the risk of adverse drug interactions, and patients may find it difficult to adhere to complex treatment regimens. Furthermore, there is evidence that many such patients will not take all of their medications as prescribed, and will attempt to 'self-optimise' their medication by trial-and-error, in order to minimise the number of medications they take whilst maximising their perceived clinical benefit. This can result in significant wastage of prescribed medication, loss of therapeutic benefit, or unsafe use of medicines.

In 2009, the prevalence of diabetes in England was 5.1%. Of those, 90% have type 2 diabetes. Coronary heart disease (CHD) is a major cause of morbidity and mortality in patients with type 2 diabetes. The sub-population of those with both type 2 diabetes and coronary heart disease is significant. It would be hugely beneficial to understand how prescriptions for this sub-population might be rationalised to minimise patient self-optimisation (and therefore potential wastage) whilst maximising real clinical benefit. We are developing an Agent-Based Simulation model with Reinforcement Learning agents to capture the self-optimising behaviours of individuals in this sub-population, to explore how well such a model could inform prescribing practices for polypharmacy patients.

■ MA-79

Monday, 8:30-10:00 - Architecture AR310, Level 3

OR for Public Health I

Stream: Operational Research for Public Health
Invited session
Chair: *Christine Currie*
Chair: *Honora Smith*
Chair: *Martin Utley*

1 - iHPS: A Service Imagery Driven Crowd Health Promotion Ecosystem
Pin-Rui Hwang

Service imagery is the presentation of service concept that is delivered through various service designs from service providers. Current health promotion service designs aim to encourage individuals to improve their health status using rational incentives, however, most of the health promotion service failed once their founding resource is exhausted. In this study, we proposed a service imagery driven health promotion service design which is noted as iHPS that facilitates the power of crowd for service innovation and value co-creation. Third party resources were introduced and integrated into iHPS. The iHPS is an imagery driven health promotion service integrated heterogeneous incentives for encouraging people to increase their health. We design a fitness mobile application noted as "i-Slim' which support and facilitate people's daily fitness exercises. The iHPS is a value co-creation crowd service that extend various linkages from the i-Slim user to social welfare institutions. Once user completes their fitness exercise through iSlim, they will be awarded with the privilege to assign some of the donations to specific social welfare institutions. The iHPS design is measured through experimental design. The measurement result indicates the iHPS could encourage and facilitate the health promotion significantly. The service imagery could be the new opportunities for improving health promotion service design.

2 - Preventing Premature Deaths: Supporting the Healthcare Economy in Wessex to Meet Future Demand for Colorectal Endoscopy
Richard Guerrero-Ludueña, Caroline Powell, Sally Brailsford

Endoscopy services across the UK are recording continuous growth and increasing demand. The demand for lower gastro-intestinal diagnostic procedures is expected to increase as a result of the ageing population, the new national NHS Bowel Cancer Screening Programme (BCSP), local initiatives to improve uptake of the BCSP, and awareness campaigns. This project aims to develop models to estimate the resource required across the healthcare economy of the Wessex region in southern England, based on a number of future scenarios, to support planning and delivery. A Discrete Event Simulation (DES) approach was used to modelling the Colorectal Cancer Pathways and the endoscopy unit across Wessex. The models were programmed in Simul8. Data were obtained from the Bowel Cancer Screening Southern Programme Hub and from the pilots of the FIT and BSSP in the UK. The results will be presented over the short term (2015) and long term (2025). We model the impact of four different intervention initiatives on future demand for endoscopy services and on the number of early cancers detected: 1) the current national BCSP using the guaiac faecal occult blood test (gFOBt), 2) Introduction of the Bowel Scope Screening Programme (BSSP) using flexible sigmoidoscopy, 3) Implementation of the Faecal Immunochemical Test (FIT), and 4) Variation in the uptake and positivity of the test.

3 - The Effect of Hospital Operator Types on Strategic Planning of Hospital Infrastructures in Germany
Verena Feld, Grit Walther

Existing hospital infrastructures in industrialized countries are subject to fundamental changes due to demographic change, rural depopulation and medical advancements. This requires simultaneous decisions about the future location of hospitals, the services offered by a hospital and the capacity (number of beds) per allocated medical service. Therefore, we have developed a multi-criteria mixed-integer programme taking into account conflicting objectives regarding the size of the network and the reallocation of beds.

Additionally, the legal regulations for the German hospital market require that hospital operator type diversity among public, not-for-profit private and for-profit private hospitals is ensured in course of the redesign of the hospital infrastructure. We discuss different approaches how this legal target can be interpreted and integrated into our optimization model. We compare the effects based on a case study for the district of Muenster as a subregion of the federal state of North Rhine-Westphalia where the federal government has recently revised the guidelines for inpatient care.

4 - Informing Decisions on the Provision of Protective Suits for Use in Decontaminating Patients Exposed to Chemical, Biological, Radiological or Nuclear Substances
Martin Utley, Luca Grieco

The possibility of events where chemical, biological, radiological or nuclear contaminants are released raises the prospect of ambulance services needing to decontaminate casualties at the scene of such an event, and of Hospitals with Emergency Departments needing to decontaminate other patients that have been exposed prior to treatment.

As part of a responsive programme of Operational Research to support health protection policy, we worked with representatives of the UK Government Department of Health and NHS England to develop an analytical framework for estimating the number of powered respirator protective suits required for individual Emergency Departments and ambulance services to meet the expected demand associated with different classes of event.

Two related models were developed: a simple clearing model relevant to the decontamination of casualties at the scene and a queueing model with time varying arrivals and a time varying, state dependent number of servers relevant to emergency departments.

We will describe the models and how they have been used in conjunction with information in the public domain and expert opinion to inform recommendations on hospital and ambulance service holdings.

■ MA-80

Monday, 8:30-10:00 - Architecture AR311, Level 3

Collaborative Transportation Planning

Stream: Transportation Planning
Invited session
Chair: *Tobias Buer*

1 - Bundle Bid Generation Strategies for Transport Auctions
Tobias Buer

Two strategies are proposed that support bidding of a freight carrier in a combinatorial transport auction. Combinatorial transport auctions are used by large shippers to procure transport services. They are also used by coalitions of carriers in order to enable collaborative transport planning through the exchange of transport requests. Both strategies are based on the notion of "elementary request combinations" and generate bids on bundle bids, that is, bids on subsets of the set of tendered requests. The first strategy exploits pairwise synergies among requests. The second strategy uses the capacitated p-median problem in order to cluster promising combinations of requests. The performance of the strategies is evaluated by means of 174 benchmark instances. On average, the heuristic strategies achieve 91 percent and 81 percent of the available sales potential while generating 36 and only 4 percent of the bundle bids of a reference strategy which guarantees the best results. Therefore, the proposed bidding strategies help a carrier to reduce the computational burden to participate in a combinatorial transport auction and make auction-based collaborative planning easier.

2 - Fair Task Allocation in Transportation
Qing Chuan Ye, Yingqian Zhang, Rommert Dekker

Task allocation problems have traditionally focused on cost optimization. However, it has become clear that service is of importance as well. Therefore, we not only want to have an optimal allocation in terms of costs, but also fairness, for the purpose of maintaining healthy competition among bidders in repeated auctions. This way bidding companies remain incentivized to participate in subsequent auctions. In this paper, we tackle this problem by splitting up the problem into two parts that we solve subsequently. We first want to determine the maximum number of jobs that can be feasibly done and the most fair distribution thereof. Since there may be many allocations that are considered equally fair, we then want to find the allocation with the least costs. We propose a polynomial-time optimal method, which consists of two novel algorithms that make use of the network flow structure of the problem to obtain the optimal solution. Furthermore, we conduct a set of extensive experiments to investigate the trade-off between cost minimization and fairness.

3 - Vertical and Horizontal Collaboration in Transportation and Inventory
Benedikt De Vos, Birger Raa

In this research we want to incorporate horizontal and vertical collaboration in a decentralized supply chain. Vertical collaboration is introduced between suppliers and their retailers through Vendor Managed Inventory in order to better align transportation and inventory management. Horizontal collaboration on the other hand is created by joining multiple suppliers and their retailers and outsourcing transportation to a Logistics Service Provider. All retailers are then replenished through jointly designed routes. The combination of vertical and horizontal collaboration allows us to reduce operational costs.

First of all, we investigated the savings of supplier coalitions by solving a series of Inventory-Routing Problems. This was done for different scenarios with varying parameters like the number of retailers and suppliers, the costs of the suppliers and Logistics Service Providers, the geographical area's size, the overlap in geographical area, etc. We searched for the coalitions with the highest savings potential and examined what parameters are important to create savings. Since collaboration is only possible on a long-term horizon, we also need to ensure that all suppliers want to stay in the coalition by giving them their fair share of the savings. So secondly, we studied how to allocate the savings using cooperative game theory and whether the coalition partners can be encouraged to choose the coalition that is most beneficial for all parties.

■ MA-82

Monday, 8:30-10:00 - Architecture AR401b, Level 4

ORAHS - EURO working group on Operational Research Applied to Health Services

Stream: Healthcare Service Improvement
Invited session
Chair: *Jennifer Morgan*

1 - Modelling the proposed 111 service in Wales
Tracey England, Dorothy Edwards, Jude Kay, Danny Antebi, John Frankish, Paul Harper

111 is the free of charge NHS telephone number that you call if you need medical help quickly and cannot wait for a doctor's appointment; however it is not for emergency calls. The 111 advisor will direct the caller to the service they need: a walk-in centre, pharmacist, out of hours GP etc.

111 became operational in England in February 2014 and in Scotland in April 2014. Currently, there is no 111 service in Scotland. There is a proposed service planned for late 2015 with the initial roll out to ABMU Health Board in October. Ahead of the planned roll out, the 111 Project Board commissioned the ABCi Modelling Unit to analyse the current NHS Direct Wales and ABMU Out-of-Hours data and develop a model for a combined service which would become 111.

The presentation will focus on the data analysis undertaken and the simulation model developed to represent the combined service, and illustrate the preliminary results from the baseline model and seven scenarios designed to predict the required workforce needed to support 111 in the ABMU region of Wales. The paper will also present initial conclusions drawn from the work and how it can be used going forward for the roll out of 111 to the rest of Wales.

2 - Robust Master Surgical Schedules
Paul Harper, Rhyd Lewis, Elizabeth Rowse, Jonathan Thompson

A major factor contributing to the high number of cancelled operations in hospitals is the unavailability of beds on hospital wards for post-operative recovery. By modelling the impact of the operating theatre timetable, the Master Surgery Schedule (MSS), on the demand for beds and vice versa, an MSS can be produced that results in a reduced number of cancelled operations, whilst also levelling the demand for beds throughout the week. In this work, a set partitioning formulation has been developed to assign surgical specialties to operating theatres, and a novel extension of the model has been used to incorporate constraints on the demand for post-operative beds. Simulation of the resulting MSS is performed in order to measure how robust the MSS is. A robust optimisation approach is investigated in order to address the stochastic nature of the factors affecting operating theatre scheduling; the results of which are compared to the deterministic formulation. This research is funded by the University Hospital of Wales; illustrative results from applying our methods to this large teaching hospital will be presented.

3 - Reinforcement learning algorithms for Jackson queueing networks: modelling the flow of patients through a healthcare system
Geraint Palmer, Paul Harper, Vincent Knight, Julie Vile

This talk will discuss the use of open queueing networks, or Jackson networks, to model flows of patients across a health system. An initial basic analytical model will be shown and compared with results obtained using a simulation model built in Python. Modelling across a whole health system using the queueing network model is particularly useful for strategic planning of resource in different healthcare settings. Our motivation and application is to the flow of elderly and frail patients within the Aneurin Bevan University Health Board in South Wales.

In reality patients do not leave one part of the system and queue for access to the next part. If there is a lack of capacity at the next destination then they remain at their current location and block other patients from proceeding. The model is extended to include this blocking.

A novel direction for this research is the potential to use reinforcement learning algorithms to find the optimal routing of patients through the health care system. The use of a particular reinforcement learning algorithm, the q-learning algorithm, on queueing networks will be explored.

4 - Classification of Critical Care Patients
Jason Young, Paul Harper, Vincent Knight, Julie Vile

How good does a classifier need to be to inform a decision model?

This talk will attempt to answer this question with a novel method of evaluating classifier algorithms. The work is presented in a healthcare setting and the potential applications will be discussed however the findings are relevant to other disciplines.

Data sets containing a number of patients along with information about each patient are considered. Patients are clustered according to their length of stay. A number of classifier algorithms are then trialled, each of which attempts to predict the cluster a new patient belongs to.

The novel part of this work is its combination with a queueing model. In the literature, the method of evaluating the performance of a classifier is to use the number of correct predictions that it makes. However, this does not show how well the information gained from the classifier can be applied to a real world problem. This can be achieved by comparing two versions of a simulation model, one with parameters from the data and the other which uses the parameters provided by the classifier. Using this methodology a best classifier is identified, both in terms of numerical results and accuracy of model. Early findings reveal that a 'best classifier' in the traditional sense does not necessarily correspond to the best classifier for a decision aid tool.

5 - Improving data quality to support patient management using text analysis

Jennifer Morgan, Vincent Knight, Paul Harper, Alex Poole, Leitchan Smith

Free-text patient record data holds a wealth of information relevant to patient management but is not easily interrogated and analysed. The objective of this work is to help one of the UKs largest healthcare providers to improve the quality and completeness of patient pathway data using text analysis. Analysis of free-text patient letters enables the systematic extraction of detailed clinical decisions to complete the data record. This allows better understanding of clinic demand and therefore timely follow-up appointments to be provided for safe and effective care.

This work presents a case study with the Ophthalmology directorate to implement a decision support tool developed to improve data completeness. The tool offers the flexibility to support manual and automated updating of the patient record depending on stakeholder buy-in, and is being used as a gateway for implementing formal text mining algorithms. In this talk we will discuss the usefulness of text analysis in healthcare, the advantages and challenges of implementing the current methods and propose practical extensions of the work.

■ MA-84

Monday, 8:30-10:00 - Architecture AR403, Level 4

Sequence and Structure

Stream: Computational Biology, Bioinformatics and Medicine
Invited session
Chair: *Marta Szachniuk*
Chair: *Jacek Blazewicz*

1 - Extracting Multiple Adjacent Classification Solutions from Viral Genomic Sequences

Emanuel Weitschek, Giulia Fiscon, Massimo Ciccozzi, Giovanni Felici

We present a new feature selection algorithm to extract multiple and locally adjacent solutions for supervised machine learning problems applied to sequenced data. In this setting, the relative position of a feature is relevant and the objective is to find set of separating features that are as close as possible to each other. Another relevant issue is to identify if multiple subsequences with the same desirable characteristics are present in the data. Our approach adopts a fast and effective method to evaluate the quality of subsequences and integrates it in a genetic algorithm. The algorithm is applied to genomic sequences from Influenza-, Polyoma-, and Rhinoviruses, and integrated in a rule-based classification framework. The method is able to efficiently extract a large number of highly accurate and compact classification rules for the three datasets. Moreover, it enables to identify several small highly informative portions of the different analyzed genomic regions.

2 - New In Silico Approach to Asess RNA Secondary Structures with Non-canonical Base Pairs

Natalia Szóstak, Agnieszka Rybarczyk, Tomasz Żok, Maciej Antczak, Ryszard Adamiak, Jacek Blazewicz, Marta Szachniuk

RNA function depends on its structure, therefore an appropriate recognition of the latter is of great importance. One particular concern is the assessment of base-base interactions, described as the secondary structure. It greatly facilitates an interpretation of RNA function and

allows for structure analysis on the tertiary level. The RNA secondary structure can be predicted from sequence using in silico methods often adjusted with experimental data, or assessed from 3D structure atom coordinates. Computational approaches consider mostly Watson-Crick and wobble base pairs. Handling of non-canonical interactions, important for a full description of RNA structure, is still a challenge. Here we present novel two-step in silico approach to asses RNA secondary structures with non-canonical base pairs. Its idea is based on predicting the RNA 3D structure from sequence or secondary structure that describes canonical base pairs only, and next, back-calculating the extended secondary structure from atom coordinates. We have integrate in a computational pipeline the functionality of two fully automated, high fidelity methods: RNAComposer for the 3D RNA structure prediction and RNApdbee for base pair annotation. We have benchmarked our pipeline on 2559 RNAs sequences with the size up to 500 nucleotides obtaining better accuracy in non-canonical base pair assessment than the compared methods that directly predict RNA secondary structure.

3 - An Agent-Based Model of the Nuclear Factor-kappa B Signalling Pathway

Richard Williams

The transcription factor NF-kB is central to the regulation of genes involved in the innate immune system, with dysregulation known to be involved in a number of inflammatory diseases. Although considerable research has been performed since its discovery in 1986, we are still not in a position to control the signalling pathway.

We believe that computational modelling and simulation of the NF-kB signalling pathway will complement wet-lab experimental approaches and facilitate a more comprehensive understanding. We have developed an agent-based model of the signalling pathway, which has been calibrated to wet-lab data. We have followed a principled approach to design and development by adherence to the CoSMoS process and believe that our model provides an abstracted view of the underlying real-world system.

Furthermore, in silico experimentation with the newly developed agent-based model, has confirmed the robust yet fragile nature of the signalling pathway. We have discovered that the pathway is robust to perturbations of cell membrane receptor component number, intermediate component number, and the temporal lag between cell membrane receptor activation and subsequent activation of the NF-kB signaling module. Conversely however, in silico experimentation predicts that the pathway is sensitive to changes in the ratio of free NF-kB to its inhibitor, and fragile to basal dissociation of the inhibited complex outside of a narrow range of probabilities.

4 - Disjoint Pathways in NMR-based Graphs

Marta Szachniuk, Lukasz Popenda

The presentation will be focused on the problem of disjoint pathways reconstruction in spectral graphs. Spectral graphs have been defined to represent the search space in the problem concerning resonance signal identification in NMR maps which are recorded during Nuclear Magnetic Resonance spectroscopy experiments aimed to determine the three-dimensional shape of biomolecule structures. Depending on the molecular structure complexity, a number of disjoint pathways should be constructed in the spectrum to support signal identification. The dimension of NMR experiment is yet additional parameter to introduce the diversity into the problem modeling procedure. Here, we present our preliminary results. We show the rules for solving the original biophysical problem and we present its graph-based model. We introduce the first algorithmic approaches applying heuristic methods to process graphs representing NMR spectra of small irregular RNA structures.

Monday, 10:30-12:00

■ MB-01

Monday, 10:30-12:00 - Barony Great Hall

Keynote Lecture: Michael Trick

Stream: Plenary, Keynote and Tutorial Sessions
Invited session
Chair: *Marco Laumanns*

1 - Business Analytics: Combining Predictive and Prescriptive Analytics to Have Broad Impact
Michael Trick

Operational Research has had tremendous impact on companies and organizations over its 70+ year history. Recent advances in algorithms, computing, and data capture have created an environment where our field can be even more influential. By combining predictive analytics, such as data mining and statistical approaches, with prescriptive analytics, such as optimization methods, our field can create systems that span multiple functions within an organization. I will discuss the key trends that are affecting the world of operational research, and illustrate the impact of those trends in my own work in sports scheduling and other application areas.

■ MB-03

Monday, 10:30-12:00 - TIC Auditorium A, Level 2

EURO New Journals

Stream: EURO Awards and Journals
Meeting session
Chair: *Martine Labbé*

1 - EURO Journal on Transportation and Logistics
Janny Leung, *Michel Bierlaire*

The EURO Journal on Transportation and Logistics is one of the three journals launched by EURO in 2011. It promotes the use of mathematics in general, and operations research in particular, in the context of transportation and logistics. It is a forum for the presentation of original mathematical models, methodologies and computational results, focussing on advanced applications in transportation and logistics. In the talk, we will discuss the aims, scope and directions of the journal, and the review process. Some statistics about the journal, as well as publication strategies will be discussed as well.

2 - EURO Journal on Decision Processes
Ahti Salo

The EURO Journal on Decision Processes (EJDP) promotes and publishes scientific knowledge on the theoretical, methodological, behavioural and organizational topics that contribute to the understanding and appropriate use of operational research in supporting different phases of decision making processes. Methodologically, EDJP covers both qualitative and quantitative approaches to the scoping, modelling and solution of decision problems. This talk highlights some of the contributions which have appeared in EJDP and presents relevant statistical information as well.

3 - The EURO Journal on Computational Optimization
Martine Labbé

We will present the EURO Journal on Computational Optimization and answer questions from the audience regarding its publication policy, scope etc.

■ MB-04

Monday, 10:30-12:00 - TIC Auditorium B, Level 2

Retail Inventory Management I

Stream: Demand and Supply in Retail and Consumer Goods
Invited session
Chair: *Ruud Teunter*

1 - A Satisficing Choice Model of Withdrawal Behavior of Perishable Items: Implications for Store Ordering
Rob Broekmeulen, *Karel van Donselaar*

We investigated the withdrawal behavior of perishable items from inventory by customers in retail stores. Our empirical study shows that the withdrawal behavior is neither strict FIFO nor LIFO. In our paper we model the observed withdrawal by the customer as the behavior of a "satisficing' decision maker who evaluates the alternatives in a given order. We explore the implications of our model for the inventory control policy at the retailer for these products, especially for the performance indicator waste.

2 - Optimal Ordering Policy and Display for Perishable Products
Zumbul Atan, *Dorothee Honhon*, *Amy Pan*

We consider the problem of a retailer managing fresh and non-fresh products. Retailers may display the fresh and non-fresh products differently. We characterize the optimal display setting and optimal ordering policy for the fresh products under different cases depending on the discount on the non-fresh products.

3 - Coordinating Replenishments under Capacity Restrictions
Gudrun Kiesmuller

In this paper we study an inventory system with multiple retailers under periodic review and stochastic demand. Linear holding and backorder as well as fixed order costs are assumed. Orders to replenish inventories can be placed at a manufacturer with a limited capacity according to a cyclic order schedule. A fixed portion of the total available capacity in a period is allocated to each retailer, each following a modified base-stock policy to determine order quantities. Thus, the order policy consists of four policy parameters for each retailer: the length of the review period, the first order point of a planning horizon, the individual capacity limit and the modified base-stock level. Replenishment orders have to be coordinated such that the capacity at the manufacturer is utilized and the replenishment costs are minimized. We present a simple heuristic to determine the parameters of the replenishment policy. For small problem instances the results of the heuristic are compared with the optimal costs and for larger problem instances we use a lower bound for the comparison. In a numerical study it is shown that the performance of the heuristic is excellent .

4 - On Spare Parts Demand Patterns and their Inventory Implications
Joern Meissner, *Laura Turrini*

Spare parts are essential for many companies because of their central role in keeping the critical equipment up and running. To find the right balance between availability and stocking costs is often very challenging due to the special characteristics of spare parts demand. That is, spare parts demand is typically slow-moving, highly stochastic, erratic and lumpy. In particular, it has been shown by previous research that it is generally not normally distributed, and that the best fitting distribution (mostly Gamma, Negative Binomial Distribution and Stuttering Poisson) depends on the mean inter-demand interval length, and on the squared coefficient of variation of demand sizes. As most inventory policies rely on distributional assumption of the demand, a wrong hypothesized distribution may result in unnecessary stock holdings and huge blocked capitals (as spare parts are often expensive), or in high penalty costs due to unplanned stock-outs. We study the case of a worldwide leader in the wind-turbines market based in Germany. We analyze their weekly demand for spare parts in the last three years for over 4000 items. We use Kolmogorov Smirnov goodness-of-fit test to find the best fitting distributions to our data and compare our results to the ones of the literature. Furthermore, we implement a slightly modified K-S test that tests the right tail of the distribution only, the very crucial information that is required to implement a successful inventory management system.

■ MB-05

Monday, 10:30-12:00 - TIC Auditorium C, Level 2

Energy Systems Analysis - Regional Investment and Dispatch Modelling

Stream: OR for Energy and Resource Efficiency
Invited session
Chair: *Hannes Hobbie*
Chair: *Dominik Möst*

1 - Optimal regional renewable energy investments under uncertainty in wind and photovoltaic generation
Hannes Hobbie, Dominik Möst

Germany is currently facing vast investments in renewable energy capacities in its electricity sector. The question is where to install generation capacities and how optimal portfolios look like considering their interactions with the (expanded) electricity grid. Modelling such investment and dispatch decisions for system planning and policy support is complex: First, wind and photovoltaic feed-in is following a stochastic nature and second, the electricity grid representation is increasing the model size extremely. In this contribution, an electricity load flow and investment model with a detailed electricity grid representation for Germany and investments in regionally highly resolved wind and photovoltaic capacities will be introduced. The investment and dispatch problem is decomposed applying Benders decomposition techniques. A stochastic feed-in of renewable energies is implemented. Time series are generated artificially through application of a stochastic vector autoregressive process showing the local wind and solar characteristics. The optimisation model calculates the (cost) optimal expansion pathway and results will show the optimal regional distribution and composition of renewable energy capacities for the targeted share on electricity supply in the year 2030. In addition, the trade-off between using cheap potentials, but far away from demand and near that are more expensive will be analysed depending on different renewable policy options.

2 - Valuation and Pricing of Electricity Delivery Contracts - the Producer's View
Raimund Kovacevic

This paper analyzes valuation and pricing of physical electricity delivery contracts. Values and prices should be consistent to production and fuel storage capacities. Using stochastic optimization problems in discrete time with general state space, the duals of production problems are used to derive no-arbitrage conditions for fuel and electricity prices as well as superhedging values and prices of OTC electricity delivery contracts. In particular we take the perspective of an electricity producer, serving contractual deliveries but avoiding unacceptable losses at the end of the planning horizon. The resulting no-arbitrage conditions, stochastic discount factors and superhedging prices account for typical frictions like limitation of storage and production capacity and for the fact that it is possible to produce electricity from fuel, but not to produce fuel from electricity. Similarities, but also substantial differences to purely financial results can be demonstrated in this way. Finally, using acceptability measures we analyze capital requirements and acceptability prices for delivery contracts, where the producer accepts some risk.

3 - Fuzzy-logic based tool for supporting the multi criteria decision-making process
Ildiko Tulbure

In almost all human activities, regardless if there are ones in the economic, environmental or social field, often there is a need to take decisions by considering several aspects, some of them indeed hardly quantifiable. In this situation there is the question what could be the most appropriate instruments which could be used in order to support the multi criteria decision-making process. A modular procedure by using a fuzzy logic based tool will be presented, where several criteria from different fields can be considered. Fuzzy logic is based on the knowledge that the reality is rather inexact than precise, because all affirmations have a certain free interpretation domain. The key notion is the linguistic variable, which makes possible the mathematical description of processes even if qualitative aspects are considered as well. To process fuzzy formulated knowledge several linguistic variables must be linked by linguistic operators. The connecting rules represent the knowledge, which is stored in a rulebase or knowledge base, similar to expert systems. Such a knowledge based approach means the methodical attempt to substitute inefficient algorithmic procedures by using

human knowledge. Thus, even partially fulfilled conditions result in partially fulfilled conclusions, so these conditions are considered also in the result. Therefore, the possibility to consider uncertain information is given, fact that is encouraging applications in different decisions making processes.

4 - A GIS-supported multi-criteria energy system optimization approach with integrated sustainability assessment
Sebastian Rauner

Energy system analysis and scenario development is a research field receiving a lot of attention in the research community. Many very comprehensive energy system models with different approaches where therefore developed to meet the challenges of an ever increasing complexity which comes with the shift of the political focus away from conventional to renewable based energy sources. However these models widely focus on the simulation or optimization of only a few key aspects, among them greenhouse gas emissions and overall cost. The resulting scenario is then allocated to the available region top-down, considering, if any, only a few constraining criteria. This approach neglects the often on regional level relevant trade-off between cost effectiveness and other impacts. This paper is therefore aiming to first elaborate on the critique of the current impact consideration in energy system models. Then an analysis of the regional energy supply and demand of Germany highlights the structure of the energy system and its clusters of impact. Finally first approaches how to include relevant impact factors of all the three sustainability dimensions, environmental, economic and social in an optimization model are presented.

■ MB-06

Monday, 10:30-12:00 - TIC Lecture Theatre, Level 1

POM Assembly Lines II

Stream: Production and Operations Management
Invited session
Chair: *Ece Sanci*

1 - Workload smoothing in assembly lines
Sadullah İmat, Meral Azizoðlu

In this research, we consider a simple assembly line balancing problem with fixed number of workstations and predefined cycle time. Our objective is to minimize the sum of the squared deviations of the workstation loads from the cycle time. We first present pure integer nonlinear programming model and then convert the model into mixed integer linear program. We develop several optimality properties and bounding mechanisms, and use them in our branch and bound algorithm. The results of our computational study reveal that our branch and bound algorithm is capable of solving medium sized problem instances in reasonable times.

2 - Rebalancing of assembly lines
Ece Sanci, Meral Azizoglu

In this study we consider assembly line rebalancing problem. We assume that the line is already configured and the task assignments are done. A disruption occurs at one or more workstations so that they will not be available thereafter. Our problem is to rebalance the line using only undisrupted workstations so as to minimize cycle time and the total disruption cost criteria. Our aim is to generate all efficient solutions with respect to our criteria. We provide mixed integer linear programming model and a branch and bound algorithm and report favorable results on their performances.

3 - Multilevel Optimization for Balancing Stochastic Assembly Lines with Buffer
Mustafa Yuzukirmizi

Assembly line balancing is a crucial operational decision which is basically assigning tasks to stations to achieve maximal production. When the task times are stochastic and there are limited buffers between stations, the problem becomes more challenging. A multilevel optimization scheme is proposed for synchronous optimization of task assignment and buffer allocation. Possible assignment combinations are generated using Constraint Programming method. Then, he combinations are evaluated using an approximate queueing network and

the best buffer allocation is determined using Powell's search algorithm. The procedure combines the advantages of both queueing theory and constraint programming. This research introduces an innovative method which integrates queueing theory to assembly line balancing in assigning tasks, evaluating the line performance and optimizing the line throughput.

■ MB-08

Monday, 10:30-12:00 - TIC Conference Room 2, Level 3

Forecasting Models

Stream: OR and Real Implementation
Invited session
Chair: *Belarmino Adenso-Diaz*

1 - Intelligent Prediction System about Dynamic Indices of Oilfield Development Based on Multi-Agent
Yihua Zhong, Jiao Zhao, Dan Wang, Yue Yongpeng, Jianhua Jin

Accurate and efficient prediction of oilfield development indexes is an important and key problem for an oilfield enterprise. Up to now, there are many prediction methods of oilfield development indexes to be proposed. With the problem that the forecasters do not know how to select the optimal predictive method from so many forecast methods, Zhong Yi-hua and her students have begun to study the problem of oilfield output since 2008. In order to apply the intelligent prediction system designed by us, this paper focuses on improving its performance by multi-agent technology. First, intelligent prediction system of oilfield development indices was analyzed and evaluated. Then, the Multi-Agent technology is introduced to optimize this intelligent prediction system. Next, a coupling model of intelligent prediction system of oilfield development indices based on Multi-Agent is presented, which divides the system into control agent layer, task agent layer and support agent layer. Finally, a simulation experiment is done and the results achieve a satisfactory level. This system may integrate all the advantages of the existing various prediction methods of oilfield development indices and provide a prediction result with relatively high accuracy by automatically selecting a predicting method according to different reservoirs and different development stages.

2 - On the design of beamforming systems with changing configurations
Cedric Yiu

Beamforming is a spatial filtering technique to enhance the required signal via a sensor array for directional signal transmission or reception. It has been studied extensively due to their wide applications in many areas such as wireless communications, biomedicine, speech recognition and acoustics. The beamforming design problem can be formulated as an optimization problem. In particular, if the beamformers are applied in the near-field of the speaker, there are various optimization methods developed for finding good designs.

In this paper, the design of broadband beamforming system is studied. When only filter coefficients are considered, the objective is to select the coefficients of the FIR filters such that the errors between the actual responses and the desired responses are minimized. Using the optimal designs, we find that when the configuration changes, the performance of the designed beamformers can improve significantly. In view of this, we propose to study the configuration design and formulate the overall problem as a non-convex optimization problem. We illustrate the proposed method by several designs and show that the design algorithm is efficient and effective.

■ MB-09

Monday, 10:30-12:00 - TIC Conference Room 3, Level 3

MAI: How to add value with business analytics: an introduction to the AnVIM methodology

Stream: Making An Impact 1 (MAI 1)
Invited session

Chair: *Giles Hindle*
Chair: *Richard Vidgen*

1 - How to add value with business analytics: an introduction to the AnVIM methodology
Giles Hindle, Richard Vidgen

Being good at analytics and predictive modelling is not enough unless it is accompanied by an understanding of the business model, the sources of value, and the opportunities for transformation. The Analytics Value Innovation Methodology (AnVIM) has been developed, through iterative application in practice, to enable analysts to bring this understanding into the analytics development process.

AnVIM draws on the soft systems methodology for business model mapping and value identification. Analysis of the business model is used to identify opportunities for analytics, which are classified in a matrix according to potential for value creation and viability. Opportunities that are high in value and viability are the focus for analytics development.

AnVIM further includes an assessment of data availability and quality, so it works both bottom-up from data or top-down from the business model and value sources, with an ambidextrous ability to explore (e.g., to find new opportunities and patterns in the data) and to exploit (e.g., to drive analytics models from known business issues and opportunities). The workshop will illustrate the AnVIM approach through a vignette of analytics usage in the food bank and telecommunications industries, and will explain how to apply it.

■ MB-12

Monday, 10:30-12:00 - TIC Conference Room 4&5, Level 3

OR and Climate Change 1

Stream: OR and Climate Change
Invited session
Chair: *Viet Anh Nguyen*

1 - Impacts of Adaptation on Mitigation Strategies: Insights from AD-MERGE
Olivier Bahn, Kelly de Bruin, Camille Fertel

Climate change is one of the greatest environmental challenges facing our planet. To address this issue, a possible strategy is the mitigation approach, which aims to reduce anthropogenic greenhouse gas (GHG) emissions. An alternative strategy is the use of adaptation to climate change impacts. Adaptation measures adjust economic or social structures to limit climate change impacts without limiting climate change itself.

The aim of this presentation is two-fold. First, we introduce in the MERGE integrated assessment model two strategies to adapt to climate changes: reactive (or 'flow') adaptation and proactive (or 'stock') adaptation. Second, we use the resulting model (AD-MERGE) to study detailed impacts of adaptation strategies on the implementation of mitigation measures in world energy sectors (namely, the deployment of clean energy technologies).

2 - Optimization Models for Energy Generation Expansion Planning in a Carbon-Constrained Environment
Semra Agrali, Ethem Canakoglu, Yildiz Arikan

In this study we consider a generation expansion planning problem of a private energy company that aims to maximize its profit while obeying the constraints on the capacity, demand and carbon emissions. In this problem, while investment decisions are made, how much to invest on the technology for carbon mitigation for certain investments or what kind of strategies should be followed to obey carbon restrictions are decided. The profit of the company is calculated by subtracting investment, operations and maintenance, production, fuel and carbon costs from the revenue obtained by producing and selling electricity and, if applied, the revenues obtained from selling carbon credits to other companies. Mixed integer linear and nonlinear programming problems are developed for this problem and the effects of the parameters on the system performance are analyzed.

3 - Optimal dynamic information acquisition with fixed cost for greenhouse gas emission taxation

Viet Anh Nguyen, Thomas Weber

We examine the optimal information acquisition policy when a decision maker can inform the optimal control of a noisy linear system, with quadratic objective function, using an informative signal of costly precision, which also carries a fixed cost each time it is invoked. The optimal policy is characterized by a variance threshold in the state uncertainty that triggers information acquisition and a nonlinear feedback law for the optimal signal precision. The findings are applied to optimal dynamic taxation of greenhouse gas emissions, in view of implementing set emissions-reduction targets. We also examine the tradeoff between control cost and likelihood of target achievement as a function of the weight the regulator puts on the state variance in the objective function.

■ MB-15

Monday, 10:30-12:00 - TIC Conference Room 6&7, Level 3

Cutting and Packing 2

Stream: Cutting and Packing
Invited session
Chair: *Ramon Alvarez-Valdes*

1 - Real World Problem Generator for the Container Loading Problem

António Ramos, Elsa Silva, José Fernando Oliveira

The Container Loading Problem (CLP) is a real-world driven, combinatorial optimization problem, with high economical, safety and environmental impact. Even though the problem has been extensively studied in the literature, there is still a huge gap between the needs of the transportation industry and what science offers, as the existing algorithms do not adequately address practical constraints, relevant for real-word needs.

We consider that one of the reasons that contribute to the discrepancy between research and practice is the absence of problems that include a large spectrum of practical relevant constraints. It is therefore a pressing need, to develop new test problems that fully reflect real world constraints, and therefore promote the development and benchmark of the new algorithms, that can be effectively used in practice.

In this work we will try to outline a problem generator which will be able to generate problem instances that fully characterize realistic constraints. The idea is to extend 2DCPackGen, a problem generator in which the properties in instances are controlled by a beta probability distribution, by adding a new set of properties to the boxes and containers, (such as weight, center of mass, friction coefficient and load bearing strength), a new set of logistics constraints (such as a VRP extension), and the stresses cargo is subject to during transportation (mechanical, biotic, chemical, and climatic transportation stresses).

2 - Packing a Superposition of Circular Objects

Edith Lucero Ozuna Espinosa, Igor Litvinchev, Luis Infante, Rafael Torres

Using a regular grid to approximate a container, packing objects is reduced to assigning objects to the nodes of the grid subject to non-overlapping constraints. The packing problem is then stated as a large scale linear 0-1 optimization problem. Valid inequalities are proposed to strengthening the formulation. This approach is applied for packing circular objects. Circular object is considered in a general sense as a set of points that are all the same distance (not necessary Euclidean) from a given point. Different shapes, such as ellipses, rhombuses, rectangles, octagons, etc. are treated similarly by simply changing the definition of the norm used to define the distance.Nesting objects inside one another is also considered. Superposition of circular objects, e.g. L-shapes and Star-shapes are also considered. Numerical results are presented to demonstrate the efficiency of the proposed approach.

3 - A GRASP-based Approach to the 2015 ESICUP Challenge

Eline Esprit, Túlio A. M. Toffolo, Tony Wauters, Greet Vanden Berghe

The mission of logistics is to get the desired goods to their destination within a certain time range, at the lowest possible cost. An important measure in minimizing transportation costs, besides better routing, is efficient container loading. As more load units can be packed inside one vehicle, the transportation cost per load unit will decrease.

The problem addressed in this work was introduced by Renault on the occasion of the 2015 ESICUP challenge. The main idea of the problem is that a large number of small items have to be packed into containers of different types and sizes. The primary objective is to minimize the volume of the shipped containers. A set of secondary objectives are considered lexicographically.

The ESICUP challenge problem can be modelled as a logic decomposition of subproblems: packing the items in stacks, selecting container types and placing the stacks in the containers. The problem differs from other problems presented in the literature in that one container should be left behind for the next shipment, provided that this container holds the smallest amount of volume and that it contains only a limited percentage of the items of each product.

The approach presented in this work consists of a multi-phase heuristic based on GRASP. At each iteration, a new solution is constructed in a greedy randomized way. After a feasible solution is obtained, different intensification strategies are applied to locally improve this solution.

4 - Delivering Products Using Pallets and Trucks

Ramon Alvarez-Valdes, Maria Teresa Alonso Martínez, Francisco Parreño, Jose Tamarit

Every week a distribution company has to decide the best way of to serve the customers' orders for each day of the week. In order to deliver the required products, they have to be put onto pallets and then the pallets loaded on trucks. The main objective is to minimize the number of trucks used while several constraints, related to the means of transport, the truck, have to be satisfied. There is a maximum weight the truck can bear as well as limits on the maximum weight per axle. For safety reasons the center of gravity has to be placed in the middle of the truck. Each order has a due date. Products cannot be served after their due date, but can be served in advance, if there is room in the trucks. Pallets can be stacked according to some rules related with their weight and the type of products.

The problem can be solved in two phases, one for building the pallets and another for loading the pallets into the truck, but our algorithm solves the problem in one phase, building and placing pallets at the same time. For each position in the truck a pallet is built, tailored for that position according to the constraints. The algorithm has a GRASP structure. At each iteration, a randomized constructive procedure builds a solution for loading all the products, and then an improvement phase tries to reduce the number of required trucks.

■ MB-16

Monday, 10:30-12:00 - TIC Conference Room 8, Level 3

Reverse Logistics and Closed Loop Supply Chains

Stream: Sustainable Supply Chains
Invited session
Chair: *Joao Quariguasi*
Chair: *Mei Cao*

1 - New Research Topics on Closed-Loop Supply Chain Management. An Analysis of the Price Elasticity of Demand of Remanufactured Products

Beatriz Jiménez-Parra, Sergio Rubio

The growing interest about activities related to Closed-Loop Supply Chain (CLSC), reverse logistics, and remanufacturing has provided a better understanding of the implications that the recovery of end-of-use products has on the business activity. Despite this fact, there are some concerns that deserve more research such as marketing issues associated to remanufactured (Reman) products (Souza, 2013). Companies interested in fostering the demand of Reman products should be conscious of the importance of knowing how the potential consumers behave in order to manage their marketing activities in the most suitable manner. For this purpose, an empirical study was performed with the aim of analyzing the key variables that explain the consumers' behaviour of Reman products (Jiménez-Parra et al., 2014). Overall, the respondents showed that price and environmental issues constitute positive motivations for their intention to purchase a Reman laptop. In

order to get more insights about price as a decision variable for consumers of Reman products, an analysis on price elasticity of demand was carried out with the aim of describing the sensitivity of consumers of Reman laptops towards changes in the price of these products, by giving a measurement of such sensitivity in terms of elasticity. The results provide interesting insights about the main characteristics of consumers of Reman products that could be useful for companies interested in the development of end-of-life strategies.

2 - Sustainable Supply Chain: The Triple-Bottom-Line and Stakeholders' Perspective
Mei Cao, Qingyu Zhang

As the pressure of global energy conservation and public awareness of environmental and social responsibility increase, sustainable development has become a core problem of any firm in managing their supply chain. Sustainable supply chain management is characterized by the contractual incompleteness and causal complexity. From the triple-bottom-line and stakeholders' perspective, the research seeks to create a framework to define, measure, and test the relationships among the constructs of sustainable supply chain exchange hazards, extent of supply chain sustainability, governance mechanism, and their related concepts.

3 - A Mathematical Model for Inventory Management and Production Planning for an Integrated Assembling-Manufacturing-Remanufacturing-Disposal System with Return Compensation
Malolan Sundararaman, Muthu Mathirajan

Original Equipment Manufacturers (OEM) are closing their supply chain by incorporating returns. In this study one such OEM who manufactures a product by assembling components is considered. The components are obtained either by manufacturing (from new raw materials) and or remanufactured (from returns) and or procured from a sub-contractor. The returns are the final product that are returned after use by the customer. The returns are obtain with a return compensation. This return compensation is a fixed price and is paid based on the quality of return. The returns are dismantled into components which are remanufactured. The components which cannot be retrieved are disposed. The assembling, manufacturing and remanufacturing operations are integrated and performed by the OEM. This integrated system has not been considered in any of the previous research literature. For such a single-product multi-component integrated assembling-manufacturing-remanufacturing-disposal system, a mathematical model to determine the optimal policy for the inventories (finished products, components, raw materials and returns) and the production (product assembly, component manufacturing, component remanufacturing, component purchased and return disposal) to minimize the total cost is developed. The results provide interesting insights for production & inventory management for an integrated assembly-manufacturing-remanufacturing-disposal system of the closed loop supply chains with return compensation

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■ MB-17
Monday, 10:30-12:00 - TIC Conference Room A, Level 9

Solutions in Game Theory

Stream: Game Theory, Solutions and Structures
Invited session
Chair: *Peter Sudhölter*

1 - On Money-back Guarantees in a Distribution Channel: Asymmetric Bargaining Power and Downstream Competition
Yufei Huang, Tingliang Huang

Money-back guarantee (MBG) is ubiquitous among retailers today. Although existing literature emphasizes the usefulness of MBG, little is known about why retailers may adopt different MBG choices in practice. To understand this, we examine retailers' MBG decisions in a distribution channel. In our model, two retailers with different quality levels first decide to use MBG or not in a normal form game, then bargain simultaneously for the wholesale price with a wholesaler, and finally take part in competition in the retail market.

We show that, the retailers' asymmetric bargaining power with the wholesaler may lead to all four possible MBG outcomes: both of the two retailers choose MBG, neither chooses MBG, or one of the retailers chooses MBG. Specially, when MBG is profitable, the retailer with higher bargaining power enjoys more flexibility, and may choose not to implement MBG, leading to asymmetric MBG outcomes in equilibrium. Sufficient conditions, as well as the economic rationales for all four MBG outcomes are discussed in the paper.

2 - New Characterizations of the Owen and Banzhaf-Owen Values Using the Intracoalitional Balanced Contribution Property
Silvia Lorenzo-Freire

This framework is focused on the study of two coalitional values: the Owen and the Banzhaf-Owen values. To this aim, we consider appealing properties and characterize both values, trying to identify their similarities and differences. All the characterizations make use of an interesting property, called intracoalitional balanced contributions and introduced in Calvo et al. According to this property, if we consider two players in the same coalition, the losses or gains for both agents when the other leaves the game are equal. This property is based on a principle of balanced contributions, which is useful not only in the case of coalitional values but also in many other contexts.

Calvo, E., Lasaga, J., and Winter, E. (1996). "The principle of balanced contributions and hierarchies of cooperation." Mathematical Social Sciences 31, 171-182.

3 - The Core of TU Games with Infinitely many Players
Miklos Pinter, David Bartl

Transferable utility cooperative games with infinitely many players are considered. We generalize the notions of core and balancedness to kappa-core and kappa-balancedness respectively, where kappa is an arbitrary infinite cardinal. We generalize also the so called Shapley-Bondareva Theorem to the infinitely many players setting, and conclude: the kappa-core of a game is not empty if and only if the game is kappa-balanced.

As in the finite player case we apply the strong duality theorem of Linear Programming, but here we need an infinite strong dualtiy theorem. Furthermore, even if our kappa-balancedness notion is very similar to the ordinary balancedness condition, it clearly shows how different the infinite many player case is from the finite many player case.

4 - Characterization of Solutions of Highway Cost Sharing Problems
Peter Sudhölter, José Manuel Zarzuelo

The problem of how to distribute the total cost of a highway among its customers who use connected parts may be modeled as a cost allocation TU game called highway game (Kuipers, Mosquera, and Zarzuelo 2013). We show that a TU game is a generalized highway game, where customers are not restricted to use connected parts, if and only if it is a nonnegative linear combination of unanimity games. By suitably translating well-known simple properties like the Davis-Maschler reduced game property (consistency) and its converse (that are, in our context, less powerful as in the traditional case) we show that the core on highway games is characterized by unanimity for two-person problems, individual rationality, consistency, and converse consistency (cf. Peleg 1986). Moreover, using the fact that the nucleolus is the unique element of the kernel if the game is convex (Maschler, Peleg, and Shapley 1972), we show, thereby generalizing the corresponding result for airport games (Potters and Sudhölter 1999), that the nucleolus is the unique single-valued (SIVA) solution that assigns equal cost shares to equal customers (satisfies ETP), charges the total cost of an exclusively used segment to its exclusive user, is scale covariant, consistent, and only depends on the cost allocation game. Finally, we show, similarly as in the traditional case (Young 1985), that the Shapley rule is characterized by SIVA, ETP, Pareto efficiency, and S-MON.

■ MB-18
Monday, 10:30-12:00 - TIC Conference Room B, Level 9

Software for Optimization Modeling 2

Stream: Software for Optimization
Invited session
Chair: *Robert Fourer*

1 - Xpress-Mosel: Modelling for Distributed and Cloud Computing
Susanne Heipcke

The increasing use of optimization models in distributed computing environments has triggered a host of new developments in the Mosel language. Besides the support of new data sources (HTTP, XML, JSON), a major concern are questions related to security for the transmission and storing of data, the protection of the model itself and the environment executing it. We also show how to use the new concept of annotations to configure FICO Optimization Modeler applications directly from the model source.

2 - Developments in the AMPL ecosystem
Christian Valente

We report new developments in the ecosystem of the AMPL modelling language; these include language constructs and operational methodologies. AMPLDev SP edition is a fully featured Integrated Development Environment (IDE) for AMPL, with workspace management, editors with syntax highlighting, solution viewers and console support. It also includes Stochastic AMPL (SAMPL), an extended version of AMPL designed to support Stochastic Programming (SP) and Robust Optimisation (RO). Formulation of RO models is greatly simplified by a subset of the extended syntax that SAMPL supports. SP models expressed in SAMPL are generated, at instance level, in SMPS format and are then solved using another component of the software suite: FortSP. FortSP is a solver designed for Stochastic Programming, based on Bender's decomposition; the performance of the solver is enhanced through regularisation by the level method. FortSP has Stochastic Integer Programming capability and uses CPLEX, Gurobi or FortMP as embedded solver. We give use case examples and discuss the benefits of the extended syntax. We are making the AMPLDev modelling system and the solvers CPLEX and FortSP more readily available to the industrial users and the academic community through a cloud-based service. AMPLDev cloud allows the users to use our software suite with a pay-as-you-go policy; the software is hosted on remote virtual machines, the computational power of which can be chosen to tailor the user's needs.

3 - OpenSolver and SolverStudio: Free Excel Add-ins for Operations Research Practitioners, Researchers and Educators
Andrew J Mason

OpenSolver and SolverStudio are two free spreadsheet add-ins that make advanced modelling tools available within Excel. OpenSolver (http://OpenSolver.org) combines the familiar Excel modelling interface with open source solvers from the COIN-OR Open Source Optimization Suite, allowing users to formulate and solve large linear and non-linear problems in Excel. Other solvers supported include Gurobi and the NOMAD derivative-free optimiser developed by GERAD. OpenSolver also provides access to the online NEOS system, allowing optimization problems to be solved in the cloud. Other features include enhanced model building and visualisation capabilities. OpenSolver has proven very popular with the OR community, with almost 120,000 downloads to date. SolverStudio (http://SolverStudio.org) is aimed at the more advanced Excel user who wishes to develop their optimization models using modelling languages such as PuLP, AMPL & GAMS. SolverStudio provides a complete modelling environment within Excel that seamlessly transfers data between the model and the spreadsheet. Users can solve models on their own computer, or run them in the cloud using the NEOS servers. SolverStudio supports a growing number of modelling languages, with the COIN-OR Math Programming Language (CMPL) and Julia/JuMP being the most recent additions. This talk will demonstrate OpenSolver and SolverStudio, present their new features and give examples of their use in industrial settings.

4 - Recent Developments in IBM ILOG CPLEX Optimizer
Xavier Nodet

Recently added features and performance enhancements will be presented. Particular emphasis will be given to mixed integer second order cone programming and quadratic programming.

■ MB-24
Monday, 10:30-12:00 - John Anderson JA3.25 Lecture Theatre

MADM Application II

Stream: MADM Applications
Invited session
Chair: *Tai-Yue Wang*

1 - The Optimal Ordering Quantity for the Deteriorated Inventories in Discontinuous Selling Stages
Tai-Yue Wang, Shih-Chern Shih-Chern Lin

Inventory management has been widely applied to production management in many industries. A good inventory management system can both help making an appropriate order quantity and decrease inventory costs significantly. Some types of inventory, such as fresh foods, would deteriorate over time and this deterioration can have a profound impact on profit. Incorporating deterioration when finding an ordering quantity is very important to decision makers. Traditional markets in developing countries have the characteristic of discontinuous selling stages. For example, for those vendors who sell fresh vegetables at both morning and evening markets, after the former has closed there is a break of several hours before the latter starts. In this study, a discontinuous selling stages model for the deteriorated product is implemented to maximize profits and finding optimal ordering quantity. Numerical case study from real world is also provided to verify this model, and sensitivity analysis is conducted to find which parameters are more influential with regard to total profits and ordering quantity. The results show that selling price and demand have greater effects on profits, while the demand parameter has a significant effect on the ordering policy. In addition, as the cycle time gets shorter, the influence of the deterioration rate function on the total profit becomes more significant.

2 - Personalized Microblog Recommendation System Based on Social Information
Hei Chia Wang

With the development of Web2.0, It's much easier to post messages on the web than before. A new type of information-sharing platform has emerged during the recent years — Microblog. This kind of platform has made it easier for users to post on the web, but leads to information overloading for the overwhelming data generated by users. It's a hard burden for users when searching on the web. Applying utilized clustering techniques to cluster documents and make personalized recommendation to target users can alleviate users' hard work on searching. However, some researches has pointed out that the document clustering methods in the past are not suitable for short snippets like microblog posts. Hence, involving semantic in short text processing to improve the results of recommendation can be considered. In this paper, a method for evaluating the similarity between microblogs based on Wikipedia, and clustering these microblogs by retrieving core terms, and then with the aid of social information, trust transitivity, and reputation is proposed. Finally, a personalized recommendation lists will be generated to target users.

3 - Measuring efficiency with Undesirable Outputs Using DEA-AR
Shiuh-Nan Hwang

Dealing with desirable outputs and undesirable outputs is important when measuring eco-efficiency. In addition, the weighting scheme of various indicators must be determined objectively. Based on the model of Hwang et al.(2013), this paper proposes a revised model to evaluate efficiency with undesirable output, which is combined the DEA-AR model and the CRITIC method proposed by Diakoulaki et al. (1995). To begin, all output variables, including desirable outputs and undesirable outputs, should be normalized to the-larger-the-better. Secondly, the ranking of output variables by importance is determined through the characteristics of the data and the correlation of inter-outputs; thus this is taken as an objective constraint. This new model possesses higher discrimination than the two models proposed by Seiford and Zhu (2002) and Hwang et al.(2013), as proved by an empirical analysis.

4 - Software Project Risk Evaluation at the Front End-A Linguistic Approach
Ching-Torng Lin

Software development (SD) has inherent uncertainties and risks. The risk evaluation and screening of software project is perhaps the most critical activity in SD, yet such risk evaluation is often not adequately performed. Limited by both the nature and the timing of SD, risk evaluation is associated with data, information and knowledge imprecise or ambiguous and fuzzy logic is well suited for dealing with decision-making in this situation. This paper presents a fuzzy logic approach for risk analysis in the development of a new software project. In this approach measurements are described subjectively by linguistic terms, while risk attributes are weighted by their corresponding importance using fuzzy values. The fuzzy logic-based risk evaluation model can efficiently aid managers in dealing with both ambiguity and complexity in new software project risk evaluation.

■ MB-25

Monday, 10:30-12:00 - John Anderson JA3.14 Lecture Theatre

Linear vector optimization and set optimization

Stream: Continuous Multiobjective Optimization and Robustness
Invited session
Chair: *Andreas Löhne*

1 - Parametric Simplex Algorithm for Linear Vector Optimization Problems
Firdevs Ulus, Birgit Rudloff, Robert J. Vanderbei

We propose a parametric simplex algorithm for solving linear vector optimization problems (LVOPs). It is a generalization of the parametric self-dual simplex algoritm, which originally is designed for solving single objective linear optimization problems and capable of solving two objective LVOPs whenever the ordering cone is the positive orthant. Our algorithm works for any dimension and it is possible to extent it to any polyhedral ordering cone C. In each iteration, the algorithm provides a set of inequalities which defines the current partition of the parameter space and correspond to a vertex of the upper image. In addition to the usual simplex arguments, one needs to eliminate the redundant inequalities from that set. This extra step is similar to the vertex enumeration procedure, which is used in most of the objective space based LVOP algorithms. Different from those, this algorithm doesn't require to solve a scalar linear program in each iteration.

2 - Bensolve - An Implementation of Benson's Algorithm to Solve Vector Linear Programmes
Benjamin Weißing

The free open source software bensolve (http://bensolve.org) utilises an Benson-like algorithm to solve vector linear programmes. Vector linear programmes (vlp) are generalisations of classical linear programmes (lp) to the case of more than one objective. Additionally, a polyhedral cone with non-empty interior containing no lines specifies the partial ordering with respect to which the optimisation takes place. In order to be able to generalise the solution-concept of scalar lp-theory to multiobjective vlp's, the originally vector-valued programme is embedded into a set-valued complete lattice. Solutions to vlp's can then be defined in terms of minimality and infimum-attainment. The upper image of a vlp is defined to be the image of the objective function over the feasible set plus (Minkowski) the ordering cone; and corresponds to the infimum of the lattice-embedded objective function values. Bensolve computes a solution to a vlp by determining a so-called vertex-representation of the upper image. To this end, an algorithm based on the outer approximation algorithm proposed by Benson in 1998 is used, where an initial polyhedral outer approximation is succesively reduced (in the subset sense) by applying cutting halfspaces. In this talk, we will give a short introduction to the vlp-theory and explain the solution concept. After these prerequisites, we are able to outline the mechanics of bensolve; with a focus on an adapted vertex-enumeration procedure.

3 - A Daniell-Stone Theorem for Aumann Integrals
Cagin Ararat, Birgit Rudloff

The Aumann integral of a measurable set-valued function is defined as the set of all (Bochner) integrals of its integrable selections. In this work, it is assumed that the set-valued functions have values in

an order-complete lattice which proves to be useful in some recent developments in vector and set optimization. The main result is a Daniell-Stone type characterization theorem for the Aumann integrals of set-valued functions. More precisely, the result characterizes the conditions under which a functional that maps from a certain collection of measurable functions into the complete lattice can be written as the Aumann integral with respect to a measure. While the set-valued analogues of the linearity and monotone convergence properties of the classical Lebesgue integral are among these conditions, the remaining properties are of geometric nature and peculiar to the set-valued framework.

4 - Solution Concepts Generated by Families of Scalar Functions
Carola Schrage, Giovanni Paolo Crespi, Andreas H. Hamel, Matteo Rocca

In ,An algorithm to solve polyhedral convex set optimization problems', a set optimization problem with polyhedral graph and polyhedral ordering cone was considered by first solving a related linear vector optimization problem, then identifying a subset of the so called pre-solution as a solution of the given optimization problem. A set in the pre-image space is considered a solution, if it is a finite infimizer, consisting of minimizers, only. Both infimizers and minimizers can be characterized through the support function of the respective images, or rather by solving a set of scalar optimization problems. In this talk, we will generalize this approach to the non-convex case and define approximate solutions in the same spirit. Notably, we do not restrict ourselves to a specific set of scalarizations, neither linear, nor translative, as is typically done in the literature. Ultimately, we will be able to prove a Weierstrass extreme value theorem.

■ MB-26

Monday, 10:30-12:00 - John Anderson JA3.17 Lecture Theatre

Combinatorial Problems in Production/Inventory/Logistics systems 2

Stream: Scheduling with Resource Constraints
Invited session
Chair: *Sergey Kovalev*

1 - Periodic Inventory Systems and Customer Behaviour
Dan Black

We examine a multi-location inventory system that is restocked at a regular period. The system allows the use of lateral or emergency transshipments to satisfy a customer demand at a location with no stock. Two common assumptions of such models is that customers will always wait for such a transshipment to arrive or that transshipments are instantaneous. These assumptions may or may not be valid. We examine these assumptions in detail extending existing models to consider transshipment lead-times and customer behaviour. We investigate whether such models can be simplified and under what situations simplifications may be valid.

2 - Improved Bounds for Cumulative Problems Using Fast Energy Reasoning
Nicolas Bonifas

We present a new algorithm to propagate the Energy Reasoning of Erschler and Lopez in subcubic time, namely $O(n2 \log n)$ time, compared to the cubic time needed for the original algorithm. Constraint programming relies on strong propagation of the problem constraints. One of the most versatile constraints to model resources in scheduling problems is the cumulative constraint, and one of the most powerful propagation for this constraint is the Energy Reasoning. Being able to propagate this constraint more efficiently is thus of great practical significance. This new result relies on newly discovered properties of Energy Reasoning and on a new data structure that uses them. We will present experimental results showing that this new algorithm is a practical improvement as well as a theoretical one.

■ MB-27

Monday, 10:30-12:00 - John Anderson JA3.27, Level 3

Applied Dynamic Stochastic Optimization and Computations

Stream: Stochastic Optimization
Invited session
Chair: *Giorgio Consigli*
Chair: *Leonidas Sakalauskas*

1 - Regulatory and market risk capital control of a P/C insurance portfolio
Giorgio Consigli

We consider a 10 year nonlinear multistage stochastic program for a portfolio manager facing stochastic liabilities from the property and casualty business and risk capital constraints compliant with an evolving regulatory framework (e.g. Solvency II). The investment universe includes liquid (Treasuries on different maturity buckets, corporates, equity, indirect real estate) and illiquid (private equity, renewables, direct real estate, infrastructures) asset classes. From a mathematical viewpoint, the elements of the optimization problems are a dynamic decision policy — the control —, a multidimensional probability space and a multi-criteria objective function with several financial and regulatory constraints. The ALM model captures the key elements of a real-world development and the risk capital constraints are studied under alternative assumptions on the assets correlation matrix leading to a set of inequalities and bounds relevant to infer the effectiveness of an optimal ALM strategy on the consumption of the allocated risk capital. Numerical results are presented for specifications of the dynamic optimization problem under alternative correlation assumptions over a long term horizon with non-homogeneous decision stages. The gap between a 1-year based standard risk capital allocation policy and the dynamic risk capital consumption is analyzed as a function of time under different risk factors correlation matrices.

2 - Portfolio choice and second order stochastic dominance
Markku Kallio, Nasim Dehghan Hardoroudi

It is well known that if portfolio A is dominated by portfolio B in second order dominance (SSD) sense then B is preferred by all expected utility maximizers with an increasing and concave utility function. Ruszczynski and Vanderbei (Econometrica, 2003) propose an LP based method where maximization of a mean-risk objective leads to optimal solutions containing one or more non-dominated portfolios in SSD sense. We show how to find such a non-dominated portfolio among the optimal ones. Furthermore, we report empirical tests using S&P500 stock return data. In these tests individuals reveal their most preferred mean-variance efficient portfolio denoted by A as well as their risk taking attitude. Thereafter, we find portfolios B and C dominating A in SSD sense. Here B is based on mean-risk optimization with risk being the expected absolute semi-deviation and C is based on expected utility maximization. Finally, individuals rank portfolios A, B and C based on their pdf of return. Results indicate that the performance of mean-variance criterion is relatively poor in the neighborhood of the minimum variance portfolio but improves as expected return increases.

3 - SP-based Decision Support for Pension Fund ALM
Vittorio Moriggia, Giorgio Consigli, Sebastiano Vitali

Stochastic Programming (SP) is proved to be a precious support to Asset-Liability managers. In this work, we implement an SP model to provide a tool for a worldwide insurance company. This tool must be capable to manage exogenous constraints, capital allocation, pension liability coverage and customized target achievement. Many improvements are made, but special attention needs a new way to manage decisional variables, split now in two separate trees.

4 - Scenario optimization: new schemes for the non-convex case
Simone Garatti, Marco Campi, Federico Alessandro Ramponi

Convex scenario optimization is a well-recognized approach to data-based optimization where the solution comes accompanied by precise generalization guarantees. It has been used in decision-making, control, and learning theory. With this work, scenario optimization breaks

into the realm of non-convex optimization. In non-convex optimization, the number of scenarios that determine the solution - the so-called support scenarios - cannot be bounded beforehand, and one has to wait until the solution is computed to assess the size of the support scenario set. A theory for non-convex scenario optimization is developed such that the generalization property of the solution is a-posteriori evaluated based on the registered number of support scenarios. The main thrust of this new perspective is that an a-posteriori judgment compensates for the lack of a-priori knowledge and leads to sharp and useful evaluations.

■ MB-28

Monday, 10:30-12:00 - John Anderson JA3.26, Level 3

Applications of Inventory Situations

Stream: Allocation Problems in Game Theory and Some Problems on Inventory and Logistics Situations
Invited session
Chair: *Erdener Ozcetin*

1 - Non-Stationary Stochastic Snventory Lot-Sizing with Emission and Service Level Constraints in a Carbon Cap-and-Trade System
Arun Purohit, Ravi Shankar

Firms worldwide are taking major initiatives to reduce the carbon footprint of their supply chains in response to the growing governmental and consumer pressures. In real life, these supply chains face stochastic and non-stationary demand but most of the studies on inventory lot-sizing problem with emission concerns consider deterministic demand. In this paper, we study the inventory lot-sizing problem with emission and cycle service level constraints under dynamic stochastic demand situation. The aim is to analyze the effects of emission parameters, product- and system-related features on the supply chain performance considering carbon cap-and-trade regulatory mechanism. Extensive computational experiments have been carried out using a mixed integer linear programming model for a large number of business settings. The analysis of results helps supply chain managers to take right decision in different demand and service level situations.

2 - An Algorithm for Integrated Multiproduct Pipeline Scheduling and Inventory Control in Distribution Terminal
Mico Kurilic

A binary model and heuristics algorithm for integrated multiproduct pipeline scheduling and inventory control in a distribution terminal are developed. Demands for each of the products are aggregated into deliveries in the increasing order of demand due times. The earliest and latest start times of product deliveries from pipeline to tanks are found from given tank capacities and product settling periods. The pipeline schedule is built one batch at the time. A batch is started by tentatively allocating the delivery that has a minimum latest start time to its latest start time slot. Adding subsequent deliveries shifts the first delivery so the batch can start earlier. Shifting allocated deliveries continues with respect to a pumping rate until the earliest start time of any delivery is not violated. The final schedule might have some pipeline shutdowns. During any iteration, the algorithm selects the product for the next delivery to be added to the schedule. The decision to increase the size of an already created batch or to start building a new batch for a different product is based on the rules that find the best tradeoffs between the pipeline schedule costs of pumping, interfaces and shutdowns and the cost of holding inventories in tanks. The rules are implemented by means of a look ahead function which provides sequencing priority to the product with the demand pattern that would result in the lowest incremental schedule and inventory costs.

3 - A Mathematical Model for the Real-Life Open Vehicle Routing Problem
Erdener Ozcetin, Gurkan Ozturk, Zehra Kamisli Ozturk, Refail Kasimbeyli, Nergiz Kasimbeyli

This work studies some real-life applications of the open vehicle routing problem (OVRP). We develop a mathematical model for the logistics problem for a company, in the form of a multi-objective OVRP. This problem is considered with different objective functions and different constraints. The mathematical models obtained are scalarized and the computational results are discussed.

■ MB-29

Monday, 10:30-12:00 - John Anderson JA4.12, Level 4

Data Analysis for Emerging Applications 2

Stream: Data Analysis for Emerging Applications
Invited session
Chair: *Fernando Paredes*

1 - Size and Prepack Optimization to Minimize Lost Sales and Logistics Costs at an Apparel Retailer
Ozgur Emre Sivrikaya, Gurhan Kok

Pre-pack optimization is a common problem in fashion retailing. Retailers pack multiple sizes of the same product (style) into the same package to minimize warehouse costs. We develop a stochastic inventory model based evaluation system for determining the optimal package configurations and the procurement amount of each package type. Live controlled experiments demonstrate a 10% increase in gross margin after taking into account a 5% increase in sales and slight increase in logistics costs.

2 - Warehouse Design with Data Mining Techniques and Picking Cost Optimization
Furkan Yener, Harun Yazgan, Enes Furkan Erkan

The aims of logistic is to transport right goods, in the desired quantity, at the accurate time, at the correct destination, with desired conditions, to the predetermined customer or partner. Warehouses are one of the fundamental components of this storage and consistent goods flow. In warehouses, there are goods received from varied destinations and goods will be prepared and shipped with regards to demands of customers. Warehouse design holds great significance in warehouse management system. The objective of the study is to reduce goods flow in warehouse area and also it will effects to reduce order delivery time. Firstly, frequency and content of orders which effects the movements in warehouse have been identified using data mining techniques. Warehouse interior design has been made by considering products associated with each other and the ratio of the purchases. Secondly, proposed and current design of the warehouse has been compared according to effectiveness. System parameters which are belongs to order delivery time are examined with statistical approach. Consequently, the proposed layout is provided lower distance and thereby lower cost is obtained.

3 - Application of heuristic Tabu Search and Particle Swarm Optimization to solving a model of optimal inventory management
Fernando Paredes, Javier Pereira, Nicolas Gaete, Claudio Fuentes, Broderick Crawford, Ricardo Soto

In this paper, we have implemented the heuristics Tabu Search and Particle Swarm Optimization for solving a model of optimal inventory management based on minimization of the expected value of lost sales considering a given level of investment as a number of replenishment orders product. The results were compared with those previously obtained by directly solving the system Karush-Kuhn-Tucker associated with a fixed-point strategy, proving that this new algorithmic resolution strategy is quite convenient method to solve the model.

■ MB-30

Monday, 10:30-12:00 - John Anderson JA5.02, Level 5

Robust Optimization in Insurance and Demand Planning

Stream: Robust Optimization
Contributed session
Chair: *Laurent Alfandari*

1 - An Approximation Approach for a Chance-Constrained Binary Knapsack Problem
Kyungsik Lee, Jinil Han, Chungmok Lee, Ki-Seok Choi, Sungsoo Park

In this talk, we propose a pseudo-polynomial time algorithm for a class of chance-constrained 0-1 knapsack problem. Our algorithm is based on the robust optimization approach to find a solution with a theoretical bound on the probability of satisfying the knapsack constraint. Computational results on a wide range of problem instances will also be presented.

2 - Newsvendor Games with Ambiguity in Demand Distributions
Xuan Vinh Doan, Tri-Dung Nguyen

We investigate newsvendor games whose payoff function is uncertain due to ambiguity in demand distributions. We discuss the concept of stability under uncertainty and introduce the concepts for robust payoff distribution when the payoff function is uncertain. Properties and numerical schemes for finding the robust solutions are presented.

3 - Nonparametric Ambiguity: Optimal Design of Insurance Contracts
Georg Pflug

We consider the problem of optimally designing an insurance contract. The optimum depends highly on the tail behaviour of the loss distribution. However, it is well known that the estimation of tails of distributions is subject to large eestimation errors.

We propose here a distributionally robust approach, which is based on a transportation distance for probability models. Based on the determination of appropriate ambiguity sets, one may find a minimax solution, by standard algorithms.

We illustrate this by examples from insurance against natural hazards.

4 - Robust In-Network Selection of Hospitals by Healthcare Insurers Under Reference Pricing
Laurent Alfandari, Victoire Denoyel, Aurelie Thiele

We propose a Robust Optimization (RO) approach for selecting a minimum-cost portfolio of hospitals by a healthcare payer, under quality constraints on the selected hospitals. This selection is made in the context of implementing a Reference Pricing (RP) new system, where the payer determines a maximum amount paid for a procedure, and the patient going to a hospital charging more than the referent price pays the difference. We provide a multinomial logit choice model for estimating the flows of patients who choose a selected hospital. This leads to a fractional integer programming formulation for the selection problem, which is solved using fractional programming techniques. In a second stage, we consider some kind of uncertainty on the parameters of the utility function of the choice model, which is generally hard to calibrate. This justifies to use a robust approach to protect the decision-maker from too large variations of these parameters. We adapt the Bertsimas and Sim RO approach to the choice model and solve the robust counterpart of the selection problem on instances of various sizes. For a given instance, simulations of variations of the uncertain parameters are conducted so as to check the average performance (in terms of cost value) of the robust solution vs the optimal solution of the variation scenario. This enables to show the effectiveness of the robust approach in this context.

■ MB-31

Monday, 10:30-12:00 - John Anderson JA5.04, Level 5

Stochastic Modeling and Simulation 1

Stream: Stochastic Modeling and Simulation in Engineering, Management and Science
Invited session
Chair: *Gerhard-Wilhelm Weber*
Chair: *Emel Savku*

1 - Analyzing the Doubly Stochastic Sequential Assignment Problem
Sheldon Jacobson, Arash Khatibi

The Doubly Stochastic Sequential Assignment Problem (DSSAP), an extension of the Sequential Stochastic Assignment Problem, is analyzed. A variety of particular instance are considered, and conditions under which the best secretary problem can be used to obtain the optimal policy for the DSSAP are discussed. An optimal assignment algorithm is also introduced that solves for the DSSAP maximum total expected reward under an arbitrary success rate distribution.

2 - Changes in the machinery and their impact on the efficiency of productivity: evaluation through discrete event simulation

Giancarlo Aquila, Luiz Celio Souza Rocha, Marcelo Nunes Fonseca, Edson Pamplona, Anderson Paulo Paiva, Paulo Rotela Junior, Victor E M Valerio

The coil processing can be a quite extensive and complex process. In this context, Simulation methodology emerges with great potential to capture the dynamical complexity observed in many companies, allowing scenario testing without having to build them in reality. The aim of this study is to evaluate the performance of a production line of an aluminum can manufacturers company, located in the southeast of the Minas Gerais state (Brazil), and also to provide a deeper knowledge of the system, enabling greater consistency in decision-making related to productivity improvement. For this purpose, the methodology used was modeling (IDEF-SIM) and discrete event simulation through Promodel® software. Two scenarios were created, an optimistic one with 20% reduction of the inefficiencies of the following machines: Bodymaker, Printer, Inside Spray and Necker and a pessimistic one with 20% increase of the inefficiency of the same machines. The results show that a loss of machines efficiency did not result in significant difference in production line performances. However, when the machines efficiency was improved the results were beneficial, with statistical significance, leading to a higher productivity system, which is desired by managers.

3 - Continuous random variates with specified skewness

John Lamb

Simulation studies need efficient random variate generators for distributions with specified properties. Efficient random variate generators are known for commonly used distributions such as the normal, lognormal, gamma and beta distributions. Here we consider a more general case where we wish to mean, variance, skewness and possibly kurtosis of a distribution but also properties of its density function. Typically, we wish to specify that the density function is unimodal. We also often wish to specify lower and upper bounds for the range of values of the distribution. For example, if a distribution represents service times, its lower bound should be zero. And we may wish to specify that the gradient of the density function tends to zero at either or both of the upper and lower bounds. Here we discuss a general method for generating efficient random variate generators with given properties and mean, variance, skewness and kurtosis. The method is based on corrected Cornish—Fisher expansions and works for a wide range of parameters and properties.

■ MB-32

Monday, 10:30-12:00 - John Anderson JA5.05, Level 5

AHP/ANP 01

Stream: Analytic Hierarchy/Network Process
Invited session
Chair: *Josef Jablonsky*

1 - A Multi-Criteria Evaluation of Impressive Criteria for Collaborative Innovation of SMEs

Irem Duzdar, Gulgun Kayakutlu, Bahar Sennaroglu

Innovative network is an unavoidable need for SMEs, since they are fragile with size of financial, technological and competence capital. SMEs may increase their limited knowledge assets by successful association with the collaborators. There is the risk of arising the problems from the organizational, cultural and institutional differences between the networking and/or collaborating SMEs. There are failure and success criteria in innovation for collaboration. In this study, these criteria are extracted which affect the innovation in SMEs from literature survey. The impressing criteria on the collaborative innovation of SMEs are extracted by literature taxonomy to classify. The objective of the classification is to rank the most effective criteria based on previously implemented cases. These results will be evaluated using the Analytic Hierarchy Process to prioritize the collaborative innovation criteria to help business to support future success. This study will enable to construct strategic roadmap using effective criteria based on managerial, technological, and cultural issues.

2 - Biodiesel Plant Site Selection with Analytic Hierarchy Process, TOPSIS and PROMETHEE

Mehpare Timor, Fatih Firat

In this study, "Biodiesel Production Plant Site Selection' problem is considered. Analytic Hierarchy Process, TOPSIS and PROMETHEE methods were used to select the best location of "Biodiesel Production Plant" on Turkey. Candidate plant locations are listed as "Adana', "Ankara', "Ordu', "Gaziantep', "Malatya', "Manisa', "Mersin', "İzmit', "Urfa' and "Tekirdağ". The process of the production of biodiesel in Turkey is described in terms of seven different criteria. These criteria are "Market' (Closeness to the market), "Area' (canola, safflower and other biodiesel raw material planting areas), "Raw Material' (Closeness to the raw materials), "Transportation' (Easiness of Transportation: Highway/Roads, Sea, Air and Railway), "Labour', "Competition' and "Incentives' (Support according to the region's development). Importance of these criteria has been determined by Analytic Hierarchy Process. And finally best biodiesel plant location was calculated by using TOPSIS method, for comparison PROMETHEE method was also used. Results of these two methods shown that "Manisa" is the best biodiesel plant location area in Turkey.

3 - Definition of Weight of Criteria in AHP by Lawshe Methodology

Antonio Neto, Eduardo Shimoda, Milton Erthal

The objective of this study was propose a method that helps in define the weight and selection of criteria to the Analytic Hierarch Process (AHP). The work was implemented in the form of a case study in the offshore environment of a large company in the oil and gas industry in Brazil, in the maintenance area, involving the board telecommunication's plant. The criteria were choose in articles and by survey applied with technical employers of the company. The employers should define the criteria as: "essential'; "important but not essential'; and "no important'. The percentage of the "essential' was used to stablish the weight of each criterion. The criteria selections were obtained comparing the Content Validity Ratio (CVR) with its critical CVR, calculated by Lawshe methodology. A range of 33 criteria were choose and the CVR allowed restrict it in 5 criteria and 10 sub-criterion. The main criteria was historical security failures (42%), followed by historical infrastructure failures (26%), strategic importance (17%), oil production (11%) and historical services failures (4%). The results were evaluated by the managers of offshore telecommunications maintenance teams and was considered approved. This methodology was useful to reduce subjectivity in defining the weights, which is inherent in the AHP. The combination of these two metologias contributes to building a democratic management decision model. Each expert influences the final result.

4 - Comparison of Prioritization Methods in the AHP
Josef Jablonsky

A crucial problem in the analytic hierarchy/network process deriving priorities form pairwise comparison matrices. The most popular methods for deriving priorities are eigenvector method proposed originally by T. Saaty, logarithmic least square method and least square method. The paper deals with other alternative approaches using goal programming methodology - one of them is based on minimization of sum of absolute or relative deviations and the other one on minimization of maximum deviation. The results of methods are compared on a set of randomly generated matrices of different sizes and consistency levels. The methods are evaluated according to several measures as the sum of absolute and relative deviations of the elements of the pairwise comparison matrix and the ratios of estimated weights, and maximum absolute and relative deviations are.

■ MB-33

Monday, 10:30-12:00 - John Anderson JA5.06, Level 5

Optimization on Riemannian Manifolds

Stream: Mathematical Programming
Invited session
Chair: *Orizon P Ferreira*

1 - Non-existence of Strictly Monotone Vector Fields on Certain Riemannian Manifolds

João Xavier da Cruz Neto, Italo Melo, Paulo Sousa

The main goal of this paper is to prove that Riemannian manifolds that admit monotone vector fields that satisfy a weaker condition than strictly monotone has infinite volume, in a sense, generalizing a result that Bishop and O'Neill proved for convex functions.

2 - A proximal point algorithm for difference of two convex functions on Hadamard manifolds

João Carlos Souza, Paulo Oliveira

A proximal point algorithm for difference of two convex functions is presented in the context of Riemannian manifolds of nonposite sectional curvature. If the sequence generated by our algorithm is bounded it is proved that every cluster point is a critical point of the function (not necessarily convex) under consideration, even if minimizations are performed inexactly at each iteration. Application in maximization problems with constraints, within the framework of Hadamard manifolds is presented.

3 - An Approach on the Proximal Point Method on Riemannian Manifolds

Glaydston Bento

In this work is presented an approach about Proximal Point Method for minimization problems in the Riemannian setting. Moreover, it is presented the Kurdyka-Lojasiewicz inequality for lower semicontinuous functions in the Riemannian context and, as an application, we present a convergence result for inexact descent methods in the Riemannian context. In particular, it is extended the applicability of proximal point method to solving any problem which may be formulated as the of minimizing a definable function (e.g. analytic) restricted to a compact manifold whose sign of the sectional curvature not is necessarily constant (for example Stiefel's manifold). Particularly, our model allows us to solving the problem of finding the p "leftmost' eigenvectors of a symmetric matrix of order n (p less than n).

4 - Concepts and techniques of optimization on the sphere

Orizon P Ferreira, Alfredo Iusem, Sandor Zoltan Nemeth

In this paper some concepts and techniques of Mathematical Programming are extended in an intrinsic way from the Euclidean space to the sphere. In particular, the notion of convex functions, variational problem and monotone vector fields are extended to the sphere and several characterizations of these notions are shown. As an application of the convexity concept, necessary and sufficient optimality conditions for constrained convex optimization problems on the sphere are derived.

■ MB-34

Monday, 10:30-12:00 - John Anderson JA5.07, Level 5

Applications in Nonlinear Optimization

Stream: Nonlinear Programming
Invited session
Chair: *Ana Maria A.C. Rocha*
Chair: *Edite M.G.P. Fernandes*

1 - Cost optimum design of doubly reinforced high strength concrete T-beams with EC-2

Ferhat Fedghouche

In this paper, a model to calculate the cost optimum design of doubly reinforced High Strength Concrete (HSC) T-beams in flexure under ultimate limit state conditions (ULS) is presented. The objective function comprises the cost of HSC, cost of steel and cost of formwork. The constraint functions are set to satisfy design requirements as per Eurocode 2 (EC-2). The cost optimization process is developed by the use of the Generalized Reduced Gradient (GRG) algorithm in the space of only a reduced number of design variables. Particular attention is paid to problem formulation, solution behavior and economic considerations. Typical example problem is considered to illustrate the applicability of the proposed design model and solution methodology. The optimized results are compared to traditional design solutions derived from conventional design office methods to evaluate the performance of the developed cost model. It is shown, among others that optimal solutions achieved using the present approach can lead to substantial savings in the amount of construction materials to be used. In addition, the proposed approach is practically simple, reliable and computationally effective compared to classical designs procedures used by designers and engineers.

2 - A new measure of optimality based on the Karush-Kuhn-Tucker conditions for sequential linear programming methods

Zsolt Csizmadia

The Karush-Kuhn-Tucker conditions are traditionally regarded as the definite first order optimality conditions for nonlinear programming, even though the regularity conditions relatively rarely hold in practice. The convergence definition of a nonlinear optimization algorithm relying on first order approximations are often quite general and focuses on the behavior of the iterates of the algorithm rather than directly on the properties of the solution. We introduce a new optimality measure derived from the Karush-Kuhn-Tucker conditions and explore the connection between the convergence of first order methods and the new measure.

3 - Automated Iterative Non-Linear Optimization for IMRT Fluence Map Optimization

Joana Matos Dias, Humberto Rocha, Tiago Ventura, Brígida Ferreira, Maria do Carmo Lopes

Radiation therapy is one of the treatments used for cancer patients. Its aim is to destroy cancer cells through radiation, but at the same time spare healthy tissue that can also be damaged by radiation. Intensity Modulated Radiation Therapy (IMRT) is one type of radiation therapy where it is possible to modulate the radiation intensities that are delivered to the patient from each radiation incidence. One of the problems that has to be solved during treatment planning is to find the best possible intensity profiles (fluence maps) for each radiation direction. This is usually done by resorting to nonlinear programming problems, forcing the treatment planner to define, by a lengthy trial and error procedure, several different parameters (like weights and lower/upper bounds). We present an automated iterative methodology for fluence map optimization, based on a fuzzy inference system, that has as major advantage the fact that it releases the human planner from trial and error procedures. Computational results using retrospective treated head-and-neck cancer patients will be shown.

■ MB-35

Monday, 10:30-12:00 - Colville C429, Level 4

DEA developments and software

Stream: DEA and Performance Measurement
Invited session
Chair: *Ali Emrouznejad*

1 - Two-Stage Network DEA: When Intermediate Measures can be Treated as Outputs from the Second Stage

Wade Cook, Sonia Aviles Sacoto, Raha Imanirad, Joe Zhu

This paper investigates efficiency measurement in a two-stage data envelopment analysis (DEA) setting. In the conventional closed serial system, the only role played by the outputs from stage 1 is to behave as inputs to stage 2. The current paper examines a variation of that system. In particular, we consider settings where the set of final outputs is comprised not only of those that result from stage 2, but can include, in addition, certain outputs from the previous (first) stage. The difficulty that this situation creates is that such outputs are attempting to play both an input and output role in the same stage. We develop a DEA-based methodology that is designed to handle such a problem. We then examine an application of this concept where the DMUs are schools of business.

2 - Penalized shape restricted least squares with an application to productivity analysis
Abolfazl Keshvari

Shape restricted regressions such as concave and convex least squares are important tools in different areas of science. Examples are found in frontier analysis, computer science, operations research, statistics and engineering. The problem is formulated as a constrained programming, in which the number of constraints is a quadratic function of the number of data points. Computing such estimators is a very difficult and time consuming task. Despite the power and usefulness of shape restricted regression in analysis of multidimensional data, the applicability of the estimator is limited mainly due to the computational burden. We propose an alternative formulation to the monotonic concave regression and present it as an unconstrained quadratic programming (QP) problem. We also present the dual problem of the penalized monotonic concave regression. Then, we relax the assumption of monotonicity, and develop an unconstrained QP to the concave regression problem. To compare the performances, we design a Monte Carlo experiment and estimate production functions using monotonic concave regression. The results of simulations show the great computational advantages of the penalized shape constrained least squares and the dual problem. We show that the bottleneck of the computational limits was the formulation of the problem, which is resolved by the approach we proposed in this paper.

3 - Merger gains in the Norwegian electricity distribution industry
Antti Saastamoinen, Endre Bjørndal, Mette Bjørndal

Electricity distribution is often considered to exhibit economies of scale. In Norway, a number of smaller distribution system operators (DSOs) exist and thus considerations to restructure the industry, possibly through mergers. This requires an examination of the possible gains of these mergers. Bogetoft and Wang (Journal of Productivity Analysis, 23, 145—171, 2005) propose a DEA-based approach to estimate potential merger gains. They identify scale and scope effects as the measures of these gains that are due to other sources than individual learning of merging companies. The Norwegian regulator estimates the potential mergers gains of DSOs based on this approach. This framework however does not account for operating environment of the DSOs. The regulator's choice of the returns-to-scale (RTS) assumption and the frontier estimator are also likely affecting to the amount of gains. We study how all these specification issues affect to the cost savings potential of the Norwegian DSO mergers. We apply a semi-nonparametric StoNED estimator as an alternative to DEA. Our results show that the gains due to the scope effects are small and that the size effects dominate. Since estimator and specification choice alter the frontier, the amount of gains is dependent from the curvature, smoothness and the RTS-properties of the frontier. The inclusion of the operating environment reduces the amount of size gains since the extra costs implied by the harsh environment are accounted for.

4 - Measuring Efficiency of Decision Making Unites: Software Uupdate for Advanced Users
Ali Emrouznejad

This paper presents software that takes its features closer to the latest developments in the DEA literature. The new software addresses a variety of issues such as: Assessments under a variety of possible assumptions of returns to scale including NIRS and NDRS; truly unlimited number of assessment units (DMUs); Analysis of groups of data by estimating automatically separate boundaries by group; Malmquist Index and its decompositions; Super efficiency; Automated removal of super-efficient outliers under user-specified criteria; Cross efficiency; Bootstrapping and models that deal with undesirable and negative data.

■ MB-36
Monday, 10:30-12:00 - Colville C430, Level 4

OR in Regular Study Programs

Stream: Initiatives for OR Education
Invited session
Chair: *Kseniia Ilchenko*
Chair: *Oleksii Molchanovskyi*

1 - An Approach to Teach Statistical Methods Using Wind Power Data
Fernando Luiz Cyrino Oliveira, José Pessanha, Reinaldo Souza

The wind has a random behavior and to cope with its variability the engineers must apply statistical and probabilistic methods in order to design and operate wind power plants. In general, the engineering students take a one semester course about probability and statistics, a short period of time to learn and develop the statistical reasoning applied to the engineering problems. In this context, it is rather important to motivate the students with examples from real problems found in the engineering practice. The purpose of this work is to describe a set of examples based on real wind speed data from public sources and designed to allow hands on activities in the classroom with the R project. The examples presented in this work are oriented to teach important concepts and methods from probability and statistics to engineering students, for example, data exploratory analysis, descriptive statistics, statistical inference, probability distribution fitting, non-parametric regression and time series analysis. In addition, the introduction of the proposed examples proposed has important practical implications, for example, it can develop and enhance the programming abilities of the students, it can improve their abilities to solve problems as well as to point out links with other disciplines like mechanics and energy conversion.

2 - Innovative Individualized Education on Time-Based Maintenance Planning
Bram de Jonge

An innovative automated approach to generate individualized assignments on time-based maintenance planning is presented. The assignment learns students to determine optimum time-based maintenance strategies using familiar spreadsheet software based on historical failure and preventive maintenance data. Topics covered by the assignment include censored data, Kaplan-Meier estimations, maximum likelihood estimations, (mixtures of) Weibull distributions, bathtub-shaped failure rates, visual goodness-of-fit tests, numerical integration, and optimization of the maintenance age. The assignment is currently used within various study programs at the University of Groningen in the Netherlands.

3 - A System Dynamic Model for the Simulation of Learning Progress Based on Empirical Data
Ulrike Maier, Axel Löffler

Examinations at the end of a one semester course at a University of Applied Sciences give at best a snap shot of the learning results at a given point of time. We are interested in a deeper analysis and evaluation of the learning progress during the duration of particular courses. In a former paper we formulated a dynamic model for the learning process of a course at university level based on the superposition of two effects (accumulation effect and segregation effect). Especially, we developed a time-discrete transition probability model between performance levels comprising the two effects. In an optimization process we calculated numerical values for the characteristic parameters of our model. Due to a lack of data concerning the pre-knowledge of the students, in our former paper we had to choose an arbitrary normal distribution of performance levels as initial state. Measurements of the initial and intermediate states are vital to validate or reject the performance levels hypothesis. Our former initial state distribution can now be replaced by empirical data (e.g., from introductory tests of the student beginners and from earlier written exams, respectively). We present optimization results for the corresponding model parameters based on the new empirical initial data and compare the simulation results with empirical examination results.

4 - A.M. Lyapunov's Methodology in the Art of Modelling for OR
Lyudmila Kuzmina

This work develops approximate methods for nonlinear analysis and synthesis in large-scale systems dynamics. A.M. Lyapunov's methodology, N.G. Chetayev's stability postulate and K.P. Persidskiy's quasi-stability postulate combined with asymptotic approach allow to establish an effective method as an additional activity tool for OR in problems of modelling of complex systems, qualitative analysis, control, synthesis. The constructed approach, founded on stability/singularity postulates, is creating an optimal systemic method for fundamental problems in dynamic systems, with subsystems of different nature (natural-scientific, social-political, ...), with strong substantiation of approximate theories. This is important for our knowledge as a whole - and for OR. It is corresponding to Antonio Gaudi's points, of that

■ MB-37

Monday, 10:30-12:00 - Colville C411, Level 4

Optimization for Sustainable Development 2

Stream: Optimization for Sustainable Development
Invited session
Chair: *Herman Mawengkang*
Chair: *Gerhard-Wilhelm Weber*

1 - The Dynamic Selection of Coordination Mechanisms in Indonesian Ministry of Religion Affairs Based on an Agent Approach

Azizah Hanim Nasution, Herman Mawengkang, Tohar Bayoangin

This paper presents and evaluates a decision making framework that enables autonomous agents to dynamically select the mechanism they employ in order to coordinate their inter-related activities in Indonesian Ministry of Religion Affairs. The framework means the coordination of mechanisms which lead to a movement from the realm of something that is imposed upon the system at design time, to something that the agents select to t their prevailing circumstances and their current coordination needs. Then agents make informed choices about when and how to coordinate and when to respond to requests for coordination. This paper describes an approach to represent coordination relationships assuming that agents inhabit an uncertain environment. We represent beliefs of CRs, utilities and actions by using influence diagrams (ID), an extension of Bayesian networks (BN). In this way, agents are able to both represent and infer how their activities affect other agents' activities, use this information to achieve a better coordinated behavior in order to improve staff performance.

2 - Modeling the Effect of Buas-Buas (Premna-pubescens Blume) Leaves Extract to the Total of Red Blood Cell and Kidney Histology Description of White Rat (Rattusnovergicus)

Martina Restuati, Syafruddin Ilyas, Salomo Hutahean, Herbert Sipahutar

This paper is based on getting empirical data about the total of red blood cell of white rats which were treated by a leaf extract from Premnapubescens Blume. A histology description from kidney's white rats treated by a leaf extract from Premnapubescens Blume, and with SRBC as antigen, is given. This research is an experimental study with a non-factorial completely randomized design. 24 rats were used in this study. The rats were divided into 4 groups. The blood of white rats was taken for an analysis of red blood cells, in total using ABX Micros 60. The data were then tabulated and analyzed by ANOVA and continued with an LSD test. The result shows that the ethanol extract of buas-buas leaves has a significant impact on the increase of red blood cell so that there could be a good significant histology kidney.

3 - Modeling Dimensional Alterations Induced in Blood Platelets and Plateletcrit of Rats by Administration of Ethanolic Extract of Plectranthus amboinicus Lour

Melva Silitonga, Syafruddin Ilyas, Salomo Hutahean, Herbert Sipahutar

Plectranthus amboinicus Lour is a medicinal plant that has many benefits, such as, as an antioxidant, hepatoprotective and immunostimulan. The aim of the present study was to investigate the effect of ethanolic extract of Plectranthus amboinicus L (EEP) leaves to the dimensions alteration of platelets PLT) and plateletcrit (PCT) in rats as a immune response. Method used. 24 male Wistar rats, 3 months in age was used in this study. Rats were divided into 4 groups, and each group consisted of 6 animals. Group I as a control group was given a 1% CMC, Group II was given 500 mg/kg bw ethanolic extract of leaves Plectranthus amboinicus (EEP), group III 500 mg/kg bw EEP+ sheep red blood cells (SRBC). Group IV was given SRBC. Treatment was given for 30 days,

SRBC was given on days 8 and 15. On day 31, blood was collected by decapitation for hematology analysis. Hematological observations include platelets, plateletcrit, MPV and PDW. Measurement of hematologic values using standard tools that ABX Micros-60. Data were analyzed by ANOVA using SPSS20 Platelets and plateletcrit significantly increased in rats given EEP + SRBC, while the EEP itself does not significantly increase the platelet and plateletcrit. Giving EEP does not have a significant influence on the MPV and PDW.Administration EEP increased the number of PLT and PCT if given antigen SRBC simultaneously

4 - Dynamic Modeling Approach for Phytoremediation of Metals to Support Sustainable Industry

Irhamni Irhamni, Herman Mawengkang

Phytoremediation can be said as the use of living green plants to detoxify contaminants from contaminated soil, water, sediments, and air. It is the most emerging field of environmental biotechnology. The plant roots have natural ability to absorb the heavy metals of the soil. The soil in industry sites, generally, is contaminated with heavy metals, such as chromium. Therefore phytoremediation can be used to clean-up the industry sites. This paper proposes a dynamic modeling approach to describe the plant — metal interaction in phytoremediation. This approach is used in order to find out time needed in the process such that the amount of metal in the soil of the industry sites meet the requirement stated by Indonesian Government.

■ MB-38

Monday, 10:30-12:00 - Colville C410, Level 4

Humanitarian Applications 2

Stream: Humanitarian Applications
Invited session
Chair: *Dilsu Ozkapici*

1 - Resource allocation for disaster response: a multi-agency approach

Oscar Rodriguez-Espindola, Pavel Albores, Christopher Brewster

After a disaster strikes, every decision counts toward protecting and providing for victims in the region and the appropriate use of those resources can make an important difference. Thus, there are several advances in the field of emergency logistics seeking to aid decision-making considering the appropriate use of resources in the response stage, usually focusing on one decision maker with control over all resources available. However, one of the main challenges faced in the field is the cooperation between different agents (government, NGOs, local organizations, international organizations) complicating the allocation of resources and tasks among them. Hence, the research proposed in this paper is aiming to consider a multi-agency approach for disaster response including a bi-objective multi-commodity multi-mode multi-period optimization model for allocation of resources and distribution in cases of flood in developing countries. The model aims to minimize the unfulfillment rate of relief items along with healthcare and sheltercare services, at the same time it minimizes the total cost of response operations and determines the number of people necessary across the available agents. The model is applied to a case study in Acapulco, México during the 2013 flood to compare the results to the activities performed by governmental authorities and provide an assessment of the results.

2 - An Intermodal Humanitarian Logistics Model Based on Maritime Transportation in Istanbul

Dilsu Ozkapici

İstanbul is the most populated city and economic capital of Turkey and it is highly prone to earthquakes. In case of an earthquake, relief items will be supplied from national and international sources. Previous studies have not considered Bosporus strait which divides the city in two sides and the opportunities of maritime transportation for relief item distribution in İstanbul. In this paper, an intermodal relief item distribution model for İstanbul involving sea and land transportation with vulnerabilities is proposed to alleviate the suffering of people in case of an earthquake. The proposed mathematical model utilizes efficiently seaports of İstanbul and maritime transportation and it allows relief item transportation between the European and Anatolian sides.

Sea-basing concept is also used for providing supply to the demand areas. It is seen that benefiting from maritime transportation and sea-basing provides flexibility for humanitarian logistics activities and the model proposed leads to an effective and reliable disaster relief system for İstanbul.

■ MB-39

Monday, 10:30-12:00 - Colville C405, Level 4

Portfolio Decision Processes

Stream: Decision Processes
Invited session
Chair: *Juuso Liesiö*

1 - Decision rules for allocation of finances to Health Systems Strengthening

Alec Morton, *Ranjeeta Thomas*, *Peter Smith*

A key dilemma in global health is how to allocate funds between disease-specific "vertical programmes" on the one hand and "horizontal programmes" which aim to strengthen the entire health system (for example by training staff, developing information systems, such as systems of vital registration, investing in distribution systems and infrastructure) on the other. While economic evaluation provides a way of approaching the prioritisation of vertical programmes amongst themselves, it provides less guidance on how to prioritise between horizontal and vertical programmes. We approach this problem by formulating a mathematical program which captures the complementary benefits of investing in both vertical and horizontal programmes. We show that our the solution to this math program has an appealing intuitive structure and demonstrate how it is readily possible to computationally solve two specialised versions of this problem, with illustrations based on the problem of allocating funding for infectious diseases in subsaharan Africa. We conclude by reflecting on how such models may be used to guide empirical data collection and theory development.

2 - Non-additive Multiattribute Utility Functions for Portfolio Decision Analysis

Juuso Liesiö

Often in multi-objective project portfolio selection the value of a portfolio is modeled as the sum of those projects' multi-attribute values that are included in the portfolio. This linear value representation is well founded in the theory of measurable value functions which assumes deterministic outcomes. However, in many applications the projects criterion specific outcomes are uncertain and should thus be modeled as random variables. In this paper we establish the preference assumption underlying the linear representation using multi-attribute utility theory. Furthermore, we show how relaxing these assumption leads to a more general class of non-additive portfolio utility functions than can capture the decision makers' risk preferences. Finally, we develop techniques to elicit these non-additive portfolio utility functions and optimization models to identify the project portfolio that maximizes the expected utility subject to resource and other portfolio feasibility constraints.

3 - Selecting a portfolio of actions with incomplete and action-dependent scenario probabilities

Eeva Vilkkumaa, *Juuso Liesiö*, *Ahti Salo*

In order to deal with major changes in the operational environment, organizations can use scenario planning to (i) build scenarios that characterize different future states of this environment, (ii) assign probabilities to these scenarios, (iii) evaluate the performance of alternative actions across the scenarios, and (iv) select those actions that are expected to perform best. We develop a portfolio model to support the selection of such actions when (i) information about the scenario probabilities is possibly incomplete and (ii) some actions can affect these scenario probabilities. This model helps select action portfolios which are resilient in that they perform relatively well in view of all available probability information, and proactive in that the actions they contain can help steer the future towards the desired direction.

4 - Binary decision diagrams for computing non-dominated project portfolios under incomplete information

Antti Toppila, *Ahti Salo*

In preference programming for selection of a set of projects, i.e. a project portfolio, the preferences over the portfolios form a partial order. Decision recommendations are based on the maximal elements in the partial order, which form the set of non-dominated (ND) portfolios. Previous algorithms for computing the ND set sequentially add portfolios to a set of potential ND portfolios until all ND portfolios are included. We present an exact branch and bound algorithm that computes the ND set by sequentially removing sets of portfolios from the set of all portfolios until only the ND portfolios remain. We use a state-of-the-art method based on binary decision diagrams (BDDs) for storing the potential non-dominated set. We discuss several bounding methods that have been used in integer programming and show how they can efficiently be implemented in the algorithm. We also report preliminary computational results on our algorithm for random test instances and examine the effectiveness of the developed bounding methods. Although these results do not indicate major computational advantages over previous methods, the algorithm has theoretically appealing characteristics. For instance, BDDs are capable of storing ND sets that have so many elements that they cannot be stored explicitly as lists. The algorithm also stores a superset of the ND set, wherefore recent methods that derive optimization bounds from BDDs may be applicable for further computational improvements.

■ MB-41

Monday, 10:30-12:00 - Colville C512, Level 5

Complex Preference Learning II

Stream: Multiple Criteria Decision Aiding
Invited session
Chair: *Milosz Kadzinski*

1 - Portfolio Decision Analysis Using Interactive Multi-objective Optimization Guided by Dominance-Based Rough Set Approach

Maria Barbati, *Salvatore Greco*, *Milosz Kadzinski*, *Roman Slowinski*

We consider the portfolio decision problem in which a set of alternatives have to be selected taking into account a set of evaluation criteria and some constraints related to limited resources. A usual approach to this type of problems consists in using Multiple Attribute Utility Theory (MAUT) and maximizing the sum of utilities associated with the alternatives entering the portfolio. Since MAUT aims at representing preferences on single alternatives, its use for evaluation of a set of alternatives makes some doubts. Thus, we propose a different approach to the problem. For each criterion we fix a certain number of reference levels corresponding to some satisfaction degrees, e.g., weakly satisficing, satisficing, very satisficing, absolutely satisficing. For each degree of satisfaction we count the number of alternatives attaining at least this level, and these numbers become the objectives to be maximized in a multiple objective optimization problem. We use Dominance-based Rough Set Approach (DRSA) to guide the search of the "best compromise' non-dominated portfolio. DRSA permits to build a preference model of the Decision Maker (DM) expressed by a set of "if. . . , then. . . ' decision rules induced from preference information supplied by the DM in terms of pairwise comparisons of some non-dominated portfolios. Decision rules permit to focus on the part of the non-dominated set most preferred by the DM.

2 - Scoring the Level of Research Results and Other Aspects of Research Impact.

Mikhail Orlov, *Boris Mirkin*

We present an approach to measuring the level of research results. The approach involves a taxonomy of the research domain, that is, a hierarchy representing the domain's structure. The level of results is evaluated according to the taxonomy ranks of the subjects that have emerged or have been crucially transformed due to the results by the scientist under consideration. We also consider two conventional approaches for scoring the research impact over (a) citation metrics and (b) merit metrics. To aggregate individual criteria we develop an automated criteria-weighting method Linstrat. The weights are chosen so that the axis of the combined criterion partitions the set of scientists under consideration in a prespecified number of strata, that are as tight as possible. These approaches are empirically tested and combined over a sample of 30 scientists in the area of data analysis, with a slightly modified part of the ACM Computing Classification System 2012 taken as

the domain taxonomy. Our main empirical results: (a) the Hirsch citation index gets a zero weight in our combined citation criterion; (b) when combining the found scales for all three dimensions, Citation, Merit, and Taxonomic rank, the latter gets the weight of 80% in the combined criterion; (c) the three dimensions are almost uncorrelated, except for a small positive correlation between the Citation and Merit.

3 - Stochastic Multicriteria Acceptability Analysis for Evaluation of Combined Heat and Power Units
Haichao Wang, *Risto Lahdelma*

In this paper, 16 CHP units representing different technologies are taken into account for multicriteria evaluation with respect to the end users' requirements. These CHP technologies cover a wide range of power outputs and fuel types. They are evaluated from the energy, economy and environment point of views. It is acknowledged that uncertainties and imprecision are common both in criteria measurements and weights, therefore the stochastic multicriteria acceptability analysis (SMAA) model is used in aiding this decision making problem. These uncertainties are treated using a probability distribution function and Monte Carlo simulation in the model. Moreover, the idea of "feasible weight space (FWS)' which represents the union of all preference information from decision makers (DMs) is proposed. A complementary judgment matrix (CJM) is introduced to determine the FWS. It can be found that the idea of FWS plus CJM is well compatible with SMAA and thus make the evaluation more reliable.

4 - Social Acceptance of Renewable Energy Technologies for Buildings in the Helsinki Metropolitan Region: Stochastic Multicriteria Acceptability Analysis of Survey Results
Nusrat Jung, *Tingting Fang*, *Risto Lahdelma*

To minimize energy consumption by buildings, the European Union (EU) has set ambitious targets for increasing the number of nearly Zero-Energy Buildings (nZEB) in the forthcoming years. Building energy performance is a key element to achieve the EU climate and energy objectives. The application of renewable energy technologies (RETs) in the residential building sector requires acceptance of technical solutions by key stakeholders. The societal acceptance of RETs is a dynamic phenomenon that evolves as people interact with new technologies available on the market. Public acceptance is an important concern in energy policy and in the marketing and implementation of RETs.

This study explores the factors which influence public acceptance of nZEB solutions and RETs in the Finnish building sector. The aim of this study is to identify: (i.) the current status of public perceptions, (ii.) social acceptance of RETs currently available on the market, and (iii.) to identify key factors, e.g., initial costs, payback time, national incentives, visibility, and barriers to acceptance.

A web based questionnaire was disseminated, with 248 respondents. Along with quantitative analysis, the results of the survey study were analyzed using Stochastic Multicriteria Acceptability Analysis to determine the ranking of current RETs. The results suggest that there are significant differences in how people perceive the various RETs, for example photovoltaic verses combined heat and power.

■ MB-42

Monday, 10:30-12:00 - McCance MC301, Level 3

Case studies in OR/Analytics 2: Production/Logistics

Stream: Case Studies in OR / Analytics
Invited session
Chair: *Sue Merchant*

1 - Development of an Autonomous Systems Development Tool to Automate Scheduling of a Batch Heat Treatment Plant
Stephen Thornton

Production scheduling software is commonplace in a wide variety of manufacturing environments globally but these systems are rarely autonomous in nature. 'AUTOPLAN', a project part funded by InnovateUK, began in 2011 to develop an 'Autonomous Systems development Tool' (ASDT) to increase potential for autonomy and enable less resource intensive, faster and more effective planning response.

This paper focuses on the experience and results gained in a Tata Steel case study, one of three used for evaluation. As well as technical aspects, the lessons learned in moving from a manual approach to autonomous operation are discussed.

After workshops and data analysis to determine hard and soft objectives, a scheduling model was built using the Preactor APS400 application. An algorithm to balance softer objectives relating to delivery reliability, energy consumption and utilisation was then added. An extended period of evaluation then followed with parallel operation and regular review with the scheduler responsible for the process.

The project has been ultimately successful in developing the ASDT but obstacles to fully autonomous deployment remain, many of which relate to continued importance of human tacit knowledge. Ancillary needs to support engendering of confidence and acceptance are also highlighted.

The outcomes of this project are also considered highly relevant in the context of the widely heralded advent of the 'fourth industrial revolution'.

2 - Long-Term Planning Model for Industrial Alumina Production
Martin Dahmen, *Stephan Westphal*

We consider the long term planning problem of simultaneous production scheduling and plant extension in the setting of an industrial alumina producer. There are several successive production steps in which basic materials and preliminary products are processed in order to produce diverse final products. As any of these steps can be processed on a selection of different machines with different capacities, the planner faces various possibilities in production scheduling and machine assignment. We present an LP-based planning procedure which takes all of the given technicalities into account and provides an optimal production schedule spanning up to five years. This solution also points out machine capacity bottlenecks and negative stocks in the long-term planning process. It also features a best choice for plant extension according to the given demand. A graphical evaluation system with heat maps for machine workload and stock balance lets the user easily get insight into the most restricting factors of any real world scenario. The model is currently in a testing phase and there is already a positive feedback from the client on the results.

3 - Combining Simulation and Optimization to Improve Picking Performance on Specialized Retailer Warehouse
João Alves, *Mário Lopes*, *Luis Guimarães*, *Bernardo Almada-Lobo*

Warehouses are crucial for supply chain operations and due to their intensive labour operations the high operation costs can be seen as a major opportunity for cost reduction. Among warehouse operations, order-picking is by far the most costly. This talk describe a collaboration project with a fashion and sports goods retailer and aims to improve the warehouse layout (selection of the best overall zone location), and zone storage assignment policy (where to locate each product in each zone) definition aiming to improve the order-picking performance. We have developed a methodology which is used to simultaneously optimize layout and storage assignment policy decisions. The methodology combines simulation with optimization and encompasses three phases. The first phase characterizes picking performance under different storage assignment policies and zones configurations trough a simulation model. Phase two is a mixed integer optimization model which defines the overall warehouse layout by selecting a configuration and a storage assignment policy for each zone among the ones studied in the previous phase. Finally the model's optimized solution is tested under uncertainty in a final simulation step. We have applied this methodology in the main retailer's warehouse. The new layout and zones policy assignment are estimated to improve picking performance by 15%. The retailer is nowadays analysing how to implement the suggested changes.

4 - How to use Collaborative Logistics
Mikael Rönnqvist

Collaboration is one important approach to develop sustainable logistic sectors. It has been shown that such collaboration in, e.g., collaborative transportation can save 10-15% of the overall cost. In addition, negative environmental impact of emissions can be reduced. With such convincing numbers all companies should be involved in such collaboration. However, this is not the case and the question is why? There are several reasons. One is the need to build the coalition but who should lead, who should take initiative and who should be invited? A second is the need to establish a sharing mechanism such that all partners are

treated fair and with respect to their effort, level of data uncertainty and specific requirements. In logistics, the evaluation of quantitative collaboration benefits is mainly conducted using Operations Research (OR) models. Game theoretic models and procedures to establish collaborative coalitions, mechanisms and sharing principles have recently gained a lot of attention in the scientific community. A third is the need to keep sensitive information classified and to have trust among all participants. This may be a problem unless the coordination is done by a third party. A number of industrial applications will be described and discussed. These arise as various transportation and logistics problems in forest and petroleum industries. Some valuable lessons have been learned which will help to improve the design of future such collaborations.

■ MB-43

Monday, 10:30-12:00 - McCance MC303, Level 3

Defence and Security Applications II

Stream: Defence and Security Applications
Invited session
Chair: *Ana Isabel Barros*

1 - One Hundred Years of Lanchester Theory
Ken McNaught

Frederick Lanchester's equations of warfare were first published in 1914 in the 'Engineering' journal but gained greater recognition in 1916 when they appeared in a book, 'Aircraft in Warfare'. Although the name 'OR' had not even been coined then, Lanchester's work provides arguably the earliest example of a formal military OR model. In this talk, 100 years later, we review the use of Lanchester's work and consider why his equations have survived for so long. The author's own small contribution to the sizeable body of Lanchester theory is also briefly reviewed.

2 - A framework for Cost-Benefit Analysis on Military Training
Marcel Smit

Estimating and optimizing training costs and benefits have been a challenge for defence analysts for decades. NATO Science and Technology Organisation (STO) working group SAS-095 identified and compared current practices of economic evaluation of military training among NATO nations, and developed a nine-step framework of economic evaluation of all types of military training at the individual, collective and/or multi-national levels. In summary, analysts need to define problem (Step 1), and then find possible solutions (Step 2). Before measuring and/or estimating military training effectiveness, costs and benefits, the analytical technique needs to be determined (Step 3). Next, analysts should determine the cost structure and estimate the costs (Step 4), determine the training effectiveness (Step 5) and estimate the benefits (Step 6) of each alternative solution. Following the comparison of alternative solutions (Step 7), analysts are required to assess risk and uncertainty (Step 8). Finally, the results are reported to the decision-makers (Step 9).

The work of SAS-095 advanced the state of common knowledge among NATO nations in economic evaluation of military training. The proposed framework will assist defence analysts in estimating training costs, monetizing training benefits, comparing and prioritizing competing training alternative solutions, and optimizing the cost and benefits in producing trained effective military forces.

3 - Improving effectiveness and/or reducing costs? A case study from the Norwegian Armed Forces
Frode Rutledal, Havard Fridheim

Over the last decade interoperable forces, defence transformation and network enabled capabilities have been buzzwords within military capability development, all aiming at improving operational effectiveness. At the same time defence budgets have been under continuous pressure, culminating with the 2008 financial crisis. Within NATO Norway has been among the countries where the Armed Forces have been least exposed to budget cuts. Nevertheless it is apparent that achieving the aims of improved effectiveness through working together, while at the same time reducing costs is a challenging exercise. This presentation is based on experiences from providing OR-support to different operational and management processes within the

Norwegian Armed forces. It investigates whether aims of increased cost-effectiveness have been met or not, and discusses key issues influencing the goal achievement.

■ MB-44

Monday, 10:30-12:00 - McCance MC319, Level 3

Fuzzy Optimization and Decision Analysis

Stream: Fuzzy Decision Support Systems, Soft Computing, Neural Network
Invited session
Chair: *Martin Gavalec*
Chair: *Jana Talasova*

1 - Duality in Intuitionistic Fuzzy Linear Programming
Milan Vlach, Jaroslav Ramik

The paper is concerned with linear programming problems whose input data may be intuitionistic fuzzy in the sense of Atanassov, while the values of variables are always real numbers. We present recent results for problems in which the notions of feasibility and optimality are based on the fuzzy relations of possibility and necessity. Special attention is devoted to the weak and strong duality.

2 - Fuzzy control in economics
Pavel Prazak

Many models in economics are formulated as optimal control problems. In such a model a rational agent aims to control a set of variables, so that the value of a given objective function would be maximized or minimized. The optimal solution usually defines the optimal state trajectory for a given initial conditions. However, in practice there are many disturbances changing the values of parameters and/or rules of the given model. Since the underlying economic processes are not fully known to us, the purely mathematical models cannot provide satisfactory results. Instead of that, the less complex principle of fuzzy regulator can be used. While applying a fuzzy regulator system, it is necessary to understand the basic principles of the given economic problem and the ways how to control it. In a fuzzy regulator model a finite set of implications is formulated and used to control the given economic problem. The aim of this contribution is to show applications of a fuzzy regulator in a simple model of central bank and a simple model of business cycles

3 - Optimization approach to unsolvable (max,min)-linear systems
Richard Cimler, Martin Gavalec, Karel Zimmermann

Algebraic structures in which a pair of binary operations (oplus, otimes) plays the same role as the addition and multiplication in the classic linear algebra can be found in the literature since the sixties of the last century. The operations are extended to Cartesian products of a finite number of such sets, which enables to formulate various (oplus, otimes)-linear problems, in which (oplus, otimes)-linear functions occur. The oplus operation is usually a commutative semi-group operation and the otimes operation is either a commutative group or semi-group operation. Moreover, the distributive law with respect to oplus, otimes is assumed. Such structures with (oplus, otimes) = (max, plus) and (oplus, otimes) = (max, min) found interesting applications and have been studied by many authors. Since the operations max and min are often used to express the membership functions of union and intersection of fuzzy sets, the (max, min)-linear problems were also applied in the fuzzy set theory. The paper deals with unsolvable (max, min)-linear equation systems with real coefficients. If the system has no solution, the nearest vector to the right hand side vector is found for which the system is solvable. A polynomial algorithm for solving the problem is presented. The method is illustrated by numerical examples.

4 - Linguistically oriented approach to fuzzy MCDM - the FuzzME software
Pavel Holeček, Jana Talasova

The FuzzME is a software tool that makes it possible to solve wide range of multiple criteria decision-making problems using fuzzy methods. This software strives to use the instrument of linguistic fuzzy modeling to the maximum extend. Experts evaluations of alternatives with respect to criteria can be set by values of linguistic variables of a special kind - linguistic scales, extended linguistic scales and linguistic scales with intermediate values. Complex evaluating functions are defined linguistically by rule bases. The resulting fuzzy evaluations computed by the FuzzME are described also verbally. For this task, a linguistic approximation is employed.

The presentation summarizes the tools of linguistic fuzzy modeling supported in the software. The methods will be demonstrated on practical examples. This will make it possible to compare their behavior and to show their strengths and weaknesses that could otherwise remain hidden behind their formulae.

■ MB-45

Monday, 10:30-12:00 - Graham Hills GH514 Lecture Theatre

Trajectories, Delays and Uncertainty in Air Traffic

Stream: Optimization of Public Transport
Invited session
Chair: *Claus Gwiggner*

1 - U.S. Airline Network Delay Characterization and Prediction

Hamsa Balakrishnan

High levels of connectivity in the air transportation system, driven in part by the desire to improve resource utilization, have contributed to the increase in flight delays. We present a new model for predicting delays in the National Airspace System (NAS), considering both temporal and spatial delay states as explanatory variables. We propose new network delay variables that characterize both the delay state of the entire NAS at a given time, as well as the type of day in terms of delays. These new variables are used as features to predict delays on different origin-destination links, a few hours in advance of their occurrence. The predictive performances of the proposed models are evaluated using operational data from major U.S. air carriers.

2 - Large Scale 4D Trajectory Planning with Uncertainties

Daniel Delahaye

To sustain the continuously increasing air traffic demand, the future air traffic management system will rely on a so-called Trajectory Based Operations (TBO) concept that will increase air traffic capacity by reducing the controllers workload. This will be achieved by transferring tactical conflict detection and resolution tasks to the strategic planning phase.In this future air traffic management paradigm context, this work presents a methodology to address such strategic trajectory planning at nation-wide and continent scale. The proposed methodology aims at minimizing the global interaction between aircraft trajectories by allocating alternative departure times, alternative horizontal flight paths, and alternative flight levels to the trajectories involved in the interaction. To improve robustness of the strategic trajectory planning, uncertainty of aircraft position and aircraft arrival time to any given position on the trajectory are considered. We propose a mathematical formulation of this strategic trajectory planning problem leading to a discrete-optimization and a mixed-integer optimization problem whose objective function relies on the new concept of interaction between trajectories. A computationally efficient algorithm to compute interaction between trajectories for large-scale applications is introduced and implemented. Resolution methods based on metaheuristic and hybrid-metaheuristic algorithms have been developed to solve the above optimization problem.

3 - A Difficulty Index for Air Traffic Control Based on Potential Conflicts

Sakae Nagaoka, Mark Brown

In airspace planning, indices which can be derived from aircraft trajectory data are needed to assess airspace complexity or safety. The

air traffic controller is still expected to play a role even in highly automated future ATM systems, and for controllers, the difficulty of handling air traffic depends partly on the circumstances of potential conflicts between aircraftFor each proximity event, the difficulty of handling a potential conflict may vary according to its projected time horizon and severity, so we have previously proposed an index based on parameters associated with the miss distance and time to closest point of approach for each pair of aircraft. However, this model is deterministic and does not consider the uncertainty of position information. As an alternative, we therefore investigate the possibility of constructing a new index of air traffic control difficulty that takes into account the uncertainty of position information. The index model deals with each conflict as a probabilistic element together with a weighting function which decays with projected time. This presentation briefly describes the mathematical model and shows some calculated examples.

4 - Swapping and Re-Sequencing Aircraft under Arrival Uncertainty

Claus Gwiggner, Sakae Nagaoka

Sequencing under arrival uncertainty can be done in two stages: Before departure, the deterministic desired times of arrival are given. Based on this, a departure sequence is established, leading to ground delays. Due to arrival time uncertainties, the sequence has to be re-scheduled after departure in order to satisfy separation constraints. This leads to en-route delays. The problem corresponds to a variant of the single machine scheduling problem with uncertain release dates. We analyzed a probabilistic sequencing policy that swaps the order of two aircraft under certain conditions. As a result, the expected total airborne delay is smaller than with traditional sequencing policies.

■ MB-48

Monday, 10:30-12:00 - Graham Hilils GH510, Level 5

Hub Location

Stream: Location
Contributed session
Chair: *Francisco Saldanha-da-Gama*

1 - The design of capacitated intermodal hub networks with different vehicle types

Elif Zeynep Serper, Sibel A. Alumur

In this study, we allow using alternative transportation modes and different types of vehicles in the hub networks to be designed. The aim of the problem is to determine the locations and capacities of hubs, which transportation modes to serve at hubs, allocation of non-hub nodes to hubs, and the number of vehicles of each type to operate on the hub network to route the demand between origin-destination pairs with minimum total cost. Total cost includes fixed costs of establishing hubs with different capacities, transportation costs, operational costs of vehicles, vehicle renting costs, and material handling costs. There is a given fleet size and it is possible to rent additional vehicles to expand it. It is assumed that each vehicle operates on a single connection. Capacity of a hub is defined as the total number of vehicles of each type which can be handled at the hub. A mixed-integer programming model is developed and a large neighborhood search algorithm is proposed for the solution of this problem. The heuristic algorithm is tested on instances from the Turkish network and CAB data set. Extensive computational analyses are conducted in order to observe the effects of changes in various problem parameters on the resulting hub networks. This research was supported by the Scientific and Technological Research Council of Turkey (TUBITAK) with grant number 111M553.

2 - Location of logistics hubs: models, methods and applicability

Carolina Luisa dos Santos Vieira, Mônica M. M. Luna

Logistics hubs are large scale facilities, where several service providers share assets in order to offer value added logistics services in a public or private area. The location of such hubs has an effect on the freight network, since to move large quantities of goods the supply chains rely on the array of links and nodes of the transportation infrastructure. This work analyses the literature on location of logistics hubs, presenting an overview of modelling approaches, solution techniques implemented and their applicability. Two main categories of models were identified,

multiple and single criteria, for which a varied set of solution methods was observed. Multiple criteria models seem suitable to tackle logistics hub location. However, they do not provide the means to assess the flows of products and their impact on the freight network. On the other hand, single criteria models, which allow dealing with both location and allocation at the same time, adopt network simplifications that do not adequately represent the relationship between hubs and goods flows. Thereby, an analytical approach may be in many cases more appropriate, solving first the location problem through a multiple criteria model, followed then by a network flow model to evaluate the impact of the new hub on the network. Other infrastructure projects could be further added, providing means to ascertain the impacts of such hubs in different scenarios.

3 - An iterated local search algorithm for fixed p-hub location and routing problems
Servet Hasgul, Zuhal Kartal, Andreas Ernst

In this study, we propose a mixed integer programming formulation of fixed hub location and vehicle routing problem. The aim of mathematical model is to allocate demand centers to the predetermined hubs, and form the vehicle routes with simultaneous pick-up and delivery of flows while visiting each demand center. The objective function of the mathematical model is to minimize the total travelling cost of routing. We present iterated local search algorithm and give computational results on the CAB data set and Turkish network.

4 - A multi-period stochastic hub location problem: formulation and valid inequalities
Francisco Saldanha-da-Gama, Isabel Correia, Stefan Nickel

In this work we study a multi-period stochastic hub location problem. Uncertainty is assumed for the flows between the origin-destination pairs. Hubs are modular and their capacity is adjustable throughout the planning horizon by changing the number of modules installed. A multiple allocation pattern is considered for the non-hub nodes. This pattern can change during the planning horizon. A two-stage stochastic programming model is initially proposed for the problem. The first stage decisions define a plan for locating the hubs and for setting up their initial capacity. The second stage decisions depend on how uncertainty is revealed and concern the adjustment of the operational capacity of the hubs (number of modules installed) as well as the routing of the flow through the network. When uncertainty can be captured by a finite set of scenarios that occur according to some known probability distribution, the extensive form of the deterministic equivalent can be derived leading to a mixed integer programming model that can be enhanced using several sets of valid inequalities. A series of computational tests was performed using a state-of-the-art solver for tackling different instances of the problem that were generated from the well-known CAB data set. The results are reported and discussed.

■ MB-49

Monday, 10:30-12:00 - Graham Hills GH511, Level 5

VNS and Scatter Search

Stream: Metaheuristics
Invited session
Chair: *Abraham Duarte*
Chair: *Nenad Mladenovic*
Chair: *Jeeu Fong Sze*

1 - Variable Neighborhood Search for determining a discount schedule which maximizes the supplier's profit
Viktoryia Buhayenko, Sin C. Ho

This research introduces Variable Neighborhood Search for the problem of determining a discount schedule in a two tier supply chain. The supplier decides how much discount should be introduced and when, to each of the customers, aiming to maximize his profit. The customers, who are heterogeneous in their demand, holding an order costs, get benefits from ordering in periods with discounts, since the resulting price reduction exceeds their increase in inventory and order costs. Solving the problem to optimality is impossible for large instances due to an exponential number of binary variables. The problem is transformed into a problem of finding the best production periods for the supplier. For this binary decision problem, a swap and a block shift neighborhood are implemented in a Variable Neighborhood Descent.

The initial solution is received by solving a problem without discounts. The objective function of each move is calculated by solving a shortest path problem for each customer and the best move is accepted. The effects on the solution quality and the run time, while changing neighborhood restrictions are investigated. The introduction of various shaking methods is presented. Shaking is performed as a random new solution generation, random changes to the current solution, as well as including a phase where worsening moves are accepted based on a probability.

2 - A hybrid heuristic for solving the car sequencing problem
Edson Senne, Antonio Chaves

The aim of this paper is to present an hybrid heuristic for the car sequencing problem (CSP), an important industrial scheduling problem. The problem consists in determining the order in which a set of vehicles must go through various stages of an assembly line in order to make the manufacturing process as economical as possible. It is an NP-hard combinatorial optimization problem and in this paper we consider only the final stage of the assembly line, in which vehicles are distinguished by different optional devices that have to be installed on them. We present a hybrid method called Clustering Search (CS), that combines the Variable Neighborhood Search (VNS) and local search heuristics. The main idea of CS is to identify promising regions of the search space by generating solutions with a metaheuristic, such as VNS, and clustering them to be further explored with local search heuristics. Computational results for the CSP considering instances available in the CSPLib repository are presented to demonstrate the efficacy of the CS.

3 - Scatter Search for the Bandpass Problem
Manuel Laguna, Jesus Sanchez-Oro, Rafael Marti, Abraham Duarte

The bandpass problem arises in the area of telecommunications. The problem consists of creating blocks of packages that need to be transmitted through a telecommunications network. The goal of the grouping is related to the reduction of the devices needed for the transmission of the packages, resulting in a decrease of both installation and maintenance costs. The input data are modeled as a m n binary matrix, where m is the number of packages and n is the number of destination points. The binary values indicate whether or not a packet must be delivered to a destination. Given a value b for the entire network, the problem is to order the rows (i.e., the packages) of the matrix in such a way that the number of bandpasses of size b is maximized. A bandpass consists of a block of b packages that are delivered to the same destination and that are arranged consecutively in the corresponding column. The problem is approached with a scatter search procedure that employs path relinking as the combination method.

4 - An adaptive Variable Neighbourhood Search for the capacitated vehicle routing problem
Jeeu Fong Sze, Said Salhi, Niaz Wassan

A variable neighbourhood search (VNS) heuristic is proposed to solve the capacitated vehicle routing problem. Two types of local search engines are used. These include: best improvement and multi-level heuristic within the VNS. In addition, a learning scheme is also embedded into the VNS combining both local searches using memory, leading to an adaptive VNS. Two diversification procedures, one based on Dijkstra's algorithm and the other using set covering method are adopted to diversify the solution. To increase the efficiency of the overall algorithm, a special data structure is designed and incorporated in the best improvement local search together with the neighbourhood reduction test. The results show a significant difference of the CPU times between the algorithm with and without these features. The combination of VNS with best improvement and multi-level heuristic appears to provide competitive result on the data sets from the literature.

■ MB-50

Monday, 10:30-12:00 - Graham Hills GH512, Level 5

Berth Allocation

Stream: Container Terminals
Invited session
Chair: *Ceyda Oguz*

1 - A Simulation Based Model for the Integrated Berth Allocation and Quay Crane Assignment Problem: A Case Study of Alexandria Container Terminal
Mostafa ABdelHafez

The need for optimisation using methods of operations research in container terminal operations has become more and more important in recent years. This is because the logistics, especially of large container terminals, has already reached such a degree of complexity that further improvements require scientific methods. The impact of concurrent methods of logistics and optimisation can no longer be judged by operations experts alone. Objective methods are necessary to support decisions. Such decisions are nowadays unthinkable without the effective and efficient use of information technology as well as optimisation and operations research methods. Typical methods used include mixed integer programming models, heuristic based methods, and in modeling the full operation of the terminal simulation based methods. This paper presents a simulation based model for the integrated Berth Allocation and Quay Crane Assignment Problems (BAQCAP) that can be used as a decision support tool for the container terminal planner to decide on the allocation that achieves the best solution according to different operational requirements. Given a specific set of vessels to process in a typical week, and the related container loading and unloading requirements, the model helps the decision maker develop a set of operational plans illustrating the different performance parameters associated with each plan. The plan includes the start time and service time for each vessel at the specified berth.

2 - The Berth Allocation Problem: Case Studies of Metaheuristics and Integer Programming
Flávia Barbosa, Mateus Pereira Martin, Antônio Moretti, Akebo Yamakami, Priscila Rampazzo

The Berth Allocation Problem, which deals with questions about allocating vessels to berths in a planning horizon in order to minimize some objective, arose amid the growth of international trade. Due to the limit of resources and the great difficulty in investing in infrastructure it is important to organize the logistics of ports and to improve their efficiencies. In Brazil, Vale company is responsible for the extraction and the exportation of iron ore, which is used to produce steel. For the company's product to be competitive and attractive in world trade, despite the long distances to the consumer market, the control of the supply chain to deliver iron ore should be improved, from its origin to the most distant countries. Economically, the most important task would be to minimize the sum of the waiting times of vessels, because some ports pay penalties if the service of a vessel takes too long to be done. However, to model this problem by Integer Programming requires the use of a large number of binary variables, whose resolution by exact methods is somewhat limited. As the number of vessels that arrive to port increases, to ensure an optimal solution could be compromised. In this context, the most appropriate approach for solving the problem are heuristics and meta-heuristics. In this work, the main object of study are Evolutionary Algorithms and Simulated Annealing opposed to Integer Programming Model, applied for Vale's company port.

3 - A New Mixed Integer Linear Model for Berth Allocation and Time-invariant Quay Crane Assignment Problems
Juan F. Correcher, Ramon Alvarez-Valdes, Jose Tamarit

In this work, we study the combined problem of berth allocation and crane assignment (BACAP) in container terminals. We consider the case of a continuous quay, so the vessels can be moored at any point of the quay in which they do not produce any overlapping, and a time-invariant crane assignment, keeping fixed the number of cranes assigned to the vessel throughout its unloading/loading process, but considering real-world aspects as the decrease of marginal productivity of quay cranes assigned to a vessel.

We have developed a new mixed integer linear programming model, adapting previous approaches to the problem considered here, and we have enhanced it by identifying and adding several families of valid inequalities. Computational experiments conducted on existing instances and new generated ones show that the proposed model can solve to optimality instances with up to 50 vessels.

4 - Berth Allocation Problem in Dry Bulk Terminals
Ceyda Oguz, Gita Taherkhani

A berth allocation problem (BAP) is the problem of assigning vessels to positions on the quay of a sea terminal to enhance the performance of the port by eliminating unnecessary delays. This research provides a mathematical model for BAPs in dry bulk terminals focusing on the partitioned BAP. Hence in the talk we will present a mixed integer linear programming (MILP) model. In the model, we partition the total length of the quay into several sections; at each section only one vessel can be allocated at a specific time. In addition, we consider the effects of the tidal condition that happens periodically in the time horizon. An underlying assumption is that, the assigned vessel to the berth location is just able to depart the terminal in the high tide periods. To evaluate the efficiency of the model, we examine the running time of the model via CPLEX. For large-size instances, CPLEX cannot generate optimal solutions and often generates an upper bound after terminating due to the time limit. To obtain tighter upper bounds, we add some valid inequalities to the MILP formulation before solving it with CPLEX. To better understand the performance of the model, we use instances generated based on the real data of a dry bulk terminal. The average time reduction and modified optimality gap show the efficiency of proposed model.

■ MB-51
Monday, 10:30-12:00 - Graham Hills GH542, Level 5

Traffic and Transportation

Stream: Traffic and Transportation
Invited session
Chair: *Jean François Wounba*

1 - Analysis of the mode of operation of traffic lights at an isolated intersection with destined for operation extended systematization vehicles
Anastasiya Shevtsova

Congestion of the road network due to the high growth of car ownership, typical for the period from 2004 to 2014 increases the cost of doing business and lead to reduction of environ-mental sustainability in the result of air pollution, and poor methods of traffic management. The growth of motorization abuseable step change in the composition of the transport stream, which has a significant effect on all parameters of the road. In most cities of the Russian Federation on roads dominated by cars, which make up 80-90% of the total population of the park. The high demand for this type of rolling stock contrib-utes to the appearance on the market of vehicles of different dimensions, such as mini cars, jeep and intermediate models with different structural features and overall length, and with that they all belong to the same type of cars. When driving in heavy traffic the difference is the overall length will affect the dynamic envelope and, therefore, the bandwidth section of the road net-work that has not previously been considered and detailed research in this area has not been con-ducted. The study was established theoretical and practical tools to enhance the functioning of isolated intersections regulated with traffic lights due to the extended classification of passenger cars on the basis of the developed in the thesis of scientific methods, principles, and mathemati-cal algorithms to collect data on isolated intersections and calculation modes of traffic lights.

2 - TEMPUS: an open-source multimodal trip planner
Romain Billot

We present a new open source multimodal trip planner dedicated to researchers (algorithms comparison) and adaptable to any new city. The operational goal of the TEMPUS project (tempus.ifsttar.fr) is to increase the quality of the information given to network users through the development and implementation of a comprehensive multimodal trip planner. TEMPUS features multimodal shortest path algorithms in order to compute the best solution from a point A to a point B. Dynamic travel time estimations are embedded as well as specific methods for multi-modal route algorithms. TEMPUS can perform one-way trip optimisation, modeling of turning movements on the road network, modeling intermodal transfers and sorting solutions according to other criteria (cost, mode transfers). Tempus is an open source C++ framework aimed at offering services to easily develop, test and compare multi-objective and multi-modal itinerary planning algorithms. It is built on a plugin-oriented architecture that enables users to develop their own algorithm of graph traversal. Part of the Tempus' API is exposed in a language-agnostic way through a WPS server. A graphical interface that allows to easily build itinerary requests and configure Tempus plugins has been developed as a Python plugin for Quantum GIS.

3 - Quality evaluation in public transport by bus services: a case study in a Brazilian medium-sized city .

Cristiano Marins

The public transportation by bus is primarily responsible for compliance with the displacement needs of the majority of the population. In the city of Campos dos Goytacazes is the primary means of public transportation and urban mobility. However, in recent years the system has experienced a crisis as a result has been the loss of quality and competitiveness of the sector and the consequent dissatisfaction of users. One way to check the efficiency would be to evaluate the performance of bus companies according to different criteria in order to identify their strengths and weaknesses. In order to contribute to the analysis of this problem, this paper presents a methodology based on the use of questionnaires to evaluate the satisfaction, agreement and importance of the criteria evaluated together with the use of statistical techniques for processing and analysis of data. Among other things, this procedure aims at assessing and ranking the public transport undertakings in the light of the evaluation criteria, as perceived by the users. By performing an experiment, we sought to investigate the application of the methodology in the assessment and classification of bus companies in the city of Campos dos Goytacazes. From the analyses it was possible to identify the most critical factors in which companies had a worse or better performance and rank them in performance categories ranging from "Very Good" to "Very Bad", in meeting users expectations.

4 - Designing an interstate transport corridors assessment platform for sub saharan transport corridors

Jean François Wounba, Alassane Balle Ndiaye, Nkeng George Elambo

The globalization of trade has contracted the distances between states using different transport approaches amongst which land transport corridors. The latter can be defined as land roads linking different economic agents and whose objective is to consolidate flow, improve infrastructure and services. Transport corridor has been experienced in different parts of the world. Nowadays, different tools have been designed to diagnose transport corridors' performances in terms of time, cost, flexibility, reliability, and security of the flows passing through the corridor.None of the above tools is designed to assess transport corridors according to their maturity stage of integrating and connecting different States. The contribution of this research is to design a multi-Criteria decision aids platform named Transport Corridor Maturity Integrated Index (TCMII), based on maturity level approaches. TCMII has many advantages; the most important one is to guide the corridor stakeholders' investment decisions by helping them to take into account the transport corridor current stage of development. This aims to minimise the risks associated with the lack of structured interventions, and to prioritise investments on the transport corridor in developig countries. Case studies have been conducted on the main interstate land corridors in Central Africa. That is the intermodal corridor (rail and road) Douala-Ndjamena, roads corridors Douala-Ndjamena and Douala-Bangui.

■ MB-52

Monday, 10:30-12:00 - Graham Hills GH554, Level 5

Financial Mathematics 2

Stream: Financial Mathematics and OR
Invited session
Chair: *Masamitsu Ohnishi*

1 - Multiple stopping problem for American type option on geometric random walk

Jun Oishi, Katsunori Ano

We study an optimal multiple stopping problem with American type reward function on geometric random walk, that is, Cox-Ross-Rubinstein market framework. Our approach is a direct study of the optimal value function for the optimal multiple stopping problem. It may be an interesting aspect that this approach does not need the general theory of optimal stopping for Markov processes. We prove that (1) there exists the multiple stopping boundaries which characterize the optimal first, second, third, ... stopping times that is the corresponding first hitting times to each boundaries, (2) these each boundaries are non-decreasing, etc.

2 - Optimal decisions of debt renegotiation, asset sale, and liquidation

Michi Nishihara, Takashi Shibata

This paper considers a situation in which shareholders of a firm in distress have a choice of whether to proceed to liquidation or debt renegotiation at an arbitrary time. We show that a lower volatility and a higher initial coupon increase the shareholders' incentive to choose debt renegotiation to avoid liquidation. When debt renegotiation is optimally chosen, the shareholders decrease the coupon of debt and use equity financing to retire a part of the debt value at the original liquidation time. The shareholders do not prefer partial asset sale in debt renegotiation unless the sale price is higher than the corresponding value of the liquidation case. We also reveal the effects of a high equity financing cost of the firm in distress. A higher equity financing cost reduces the value of debt renegotiation by suppressing the coupon reduction, and then, it increases the shareholders' incentive to liquidate the firm.

3 - Multi-Period Investment Policy for Corporate Pension Fund with Sponsoring Company

Muneki Kawaguchi, Norio Hibiki

We propose an optimization model to obtain multi-period corporate pension investment strategy in consideration of the characteristics of sponsoring company and pension fund, economic condition. We analyze the impact of the optimal investment strategy for the pension fund. We extend a multi-period stochastic programming model to obtain optimal investment strategy from sample paths of business return and asset returns. We describe the characteristics of these returns using a regime switching model. The distributions of the sample paths of these returns depend on economic condition in our model. The information which the investors get about economic condition is expressed as the state probability on the regime switching model. The optimal asset allocation given by our model depends on the state probability. There are two types of views on pension management, short-term view and long-term view. The assumption for economic condition differs between two types of views. The parameters of our model are estimated with financial market data and accounting information on the basis of the difference between two types of views. We investigate what kinds of characteristics of pension fund and sponsoring company are sensitive to investment strategy or the amplitude of asset allocation. We find the sponsoring company which has higher sensitivity for economic condition should adopt the more sensitive investment strategy.

4 - Lundberg model of the ruin probability for insurance company with asset management

Yasuhiro Ouchi, Katsunori Ano

It may be known the difficulty to solve the ruin probability explicitly even for Lundberg model for insurance company. This paper gives the numerical results of the ruin probability of the extended Lundberg model that takes into account the asset management of insurance company, using the Monte Carlo method. We examine the performance for the many new effects for the bankruptcy probability of the insurance company.

■ MB-53

Monday, 10:30-12:00 - Graham Hills GH614, Level 6

Dynamic Programming and Its Applications 1

Stream: Dynamical Systems and Mathematical Modelling in OR
Invited session
Chair: *Masayuki Horiguchi*

1 - Elimination and Insertion Operations for Finite Markov Chains

Constantine Steinberg, Isaac Sonin

A Markov chain (MC) observed only when it is outside of a subset D is again a MC with a well-known transition matrix P_D. This matrix can be obtained also in a few iterations, each requiring O(n2) operations, when the states from D are 'eliminated' one at a time. We modify these iterations to allow for a state previously eliminated to be 'reinserted' into the state space in one iteration. This modification sheds a new light on the relationship between an initial and censored MC, and

introduces a new operation, which we call 'insertion', into the theory of MCs. This operation is used to obtain an algorithmic solution to the new class of applied probability models, where at each moment of a discrete time a decision maker can apply one of three possible actions - continue, quit and restart the MC in one of a finite number of fixed 'restarting' points. Such a model is a generalization of a model of Katehakis and Veinott (1987), where a restart to a unique point was allowed without any fee and quit action was absent. Both models are related to Gittins index and another index defined in a Whittle family of stopping retirement problems. The connection to financial mathematics was provided by El. Karoui N., Bank P.; A stochastic representation theorem with applications to optimization and obstacle problems (2002), and Bank P. Follmer H.; American options, multi-armed bandits, and optimal consumption plans: a unifying view. Lect. Notes Math. (2003)

2 - On one inventory problem proposed by I.M.Sonin
Ernst Presman

Sonin considered the following problem. There is a firm using for production commodity which is consumed with a unit intensity. The price for the commodity is a continuous time Markov chain with a finite number N of states and known transition rates. A firm can buy a commodity on a current price or use the "stored' commodity. It can buy either with some intensity or instantly some amount for storage. The storage cost is proportional to the amount of stored commodities. The goal is to minimize the average (or discounted) performance cost which equals to the storage cost plus purchase cost.

Sonin supposed that the optimal strategy has the following threshold character. For any state i of Markov chain there exists a(i) such that if the storage level y is less than a(i) then the firm byu instantly the amount a(i)-y. If y=a(i) then the firm byu the commodity with the unit intensity till the next jump of the Markov chain, keeping the amount of the stored commodity at the level a(i). If y>a(i) then the firm does not buy and use for production the stored commodity till the next jump of Markov chain or till the time when storage level will be equal to a(i).

For N=2 and for some subcases N=3, Sonin found the minimal values of thresholds in the class of threshold strategies. We consider a general case, prove that the optimal strategy is indeed the threshold one, and give an algorithm of sequential construction of optimal thresholds beginning from the smallest one.

3 - Optimal strategy to get a Free Agent batter by optimal batting order model on Markov chain.
Takehiro Takano, Katsunori Ano

This paper studies the optimal strategy to get a Free Agent batter in order to maximize the expected run per one game using the optimal batting order model, which based on Markov chain property of the baseball game. The home-run batter may increase the expected run, but sometimes the average hitter does it more than home-run batter. This indicates that the trading strategy should be evaluated in the batting order of the team. We show the numerical examples for Nippon Professional Baseball.

4 - Markov decision processes with unknown transition matrices: communicating case.
Masayuki Horiguchi

We treat a learning algorithm in finite Markov decision processes with unknown transition matrices. We introduce vanishing discount rate in order to have average optimal policy which is given by Dynamic programming equation. By using the algorithm of reward-penalty type an adaptively optimal policy and an asymptotic sequence of adaptive policies with nearly optimal properties in average reward criteria is shown. An algorithm is constructed of MLE of the unknown transition matrices and sequential updating of probabilities of transition matrices.

■ MB-54

Monday, 10:30-12:00 - Graham Hills GH617, Level 6

Management Accounting and Control 2

Stream: Experimental Perspectives and Challenges in Management Accounting and Management Control
Invited session
Chair: *Stephan Leitner*
Chair: *Julián Benavides*

1 - Is the cost function still linear? "An Egyptian case study'
Bassam Baroma

Purpose: The main objective of this study is to estimate the cost function behavior amid the new manufacturing environment. Because accountants have always assumed linearity of the cost function and economists the converse (non-linearity), this study's goal is to discover its actual behavior (linear or non-linear). Because volume base was considered the main driver behind all production costs, accountants assumed the aforementioned. *Design/methodology/approach: This study depends upon descriptive and inductive extrapolations of the cost function: by collecting actual cost data from two companies. The first one represents traditional manufacturing environment (T) whilst the second new manufacturing environment (M) for 24 months from 1/1/2010- 1/1/2012. *Findings: Results indicate that the best model to represent the cost function for (T) company is non-linear (logarithmic model) (R2 =92.1%); second ensues the multiple linear one (R2 =89.8%), suggesting an error assumption within the linear cost function under the traditional production environment. conversely, the best model for (M) company is in fact the multiple linear one (R2 =71.2%), following its non-linear counterpart (logarithmic model) (R2 =67.2%). *key words: linear cost function, non-linear cost function, cost classification, Activity Based Costing, Egypt

2 - Financial Model for Optimal Decision Making for the Operation and Growth of a Shopping Center
Julián Benavides, Felipe Henao

We develop a model of financial optimization with dynamic levels of debt, which seeks to define the optimal level of decision variables concerning the operation and growth of a shopping center (SC). The ultimate purpose of the management of a SC is to generate traffic (visitors) of potential buyers and users. A regression analysis of the number of visitors confirmed the causal link between the physical area of the CC (square meters of private areas) and the number of visitors. This implies that the SC should make expansion and renovation projects in the coming years. Then, significant amounts of capital must be obtained via cash flow or debt. Thus, the level of the administration fee, project debt levels and the premises sale or rental of future expansions affects both the implementation of future growth projects, as much as the profitability and future value for current and future investors. The problem poses a dynamic debt relationship where higher levels of administration fees contribute to the breakeven of the ongoing operations releasing resources to the amortization of the debt related to expansion projects, while lower levels ease the operational burden of the co-owners in the short term, but increase the indebtedness and postpone the execution of expansion projects. The result is a trade-off around the administration fee between the operation of the SC and the private business of the joint owners, supplemented by the additional effects of the other decision variables.

■ MB-55

Monday, 10:30-12:00 - Graham Hills GH626, Level 6

Pricing of Financial Instruments

Stream: Data Mining in Finance and Commodities
Invited session
Chair: *Saptarshi Ray*
Chair: *Dejan Stokic*
Chair: *Marcus Hildmann*

1 - Investigating the impacts from tail-fatness on option pricing and hedging by an asset return model based on normal and asymmetric Laplace mixture distribution
Daniel Miao

The distributional properties of an asset's return are known to play significant roles in option pricing or hedging issues involved with this asset. Traditionally skewness and kurtosis are used to measure the extents of asymmetry and tail-fatness which provide useful information about its deviation from normality. Despite their wide use, it remains questionable regarding whether specifying these two measures only is sufficient and whether other significant information is lost. To investigate, we propose a flexible asset return model based on a standardised

version of the normal and asymmetric Laplace (SNAL) mixture distribution which is able to generate arbitrarily large kurtosis for any level of skewness. For a given pair of skewness and kurtosis, it has additional free parameters that provide more delicate information about tail-fatness which cannot be captured by skewness and kurtosis. Under this model, the exact formulas for European option price and hedging parameters are derived in closed form and are compared to the approximate formulas based on Gram-Charlier and Edgeworth series expansion to examine the information loss by using skewness and kurtosis only. Our results show that the additional tail-fatness parameters explain a significant portion of the variations as seen in the shape of the implied volatility smiles and the construction of hedging portfolios, suggesting the necessity of using more parameters than skewness and kurtosis.

2 - Association rules mining and cross correlation using Apriori algorithm to the financial market: The case with respect to UK Stock market and Global cues
Saptarshi Ray

In the era of globalisation, stock market and all the other financial markets in the world are not independent now a days. The particular stock market performance depends on the various other global factors. In this globalised economy one country stock market performance does not depend only on the particular country economy. This paper is an attempt to study the effect of global cues on London stock indices. This paper has taken the consideration of some other macroeconomic factor of the country like LIBOR, Central bank rate etc. All these factors have been taken into consideration for this analysis. The data from London stock exchange will be downloaded for the period of last 5 years comprising of daily transactions. Same time period data will be downloaded from the official websites of World gold council, LIBOR, daily exchange rate of four strong currencies over the world. Couple of different methods will be used to analyse the pattern and the association between various time series. This paper has tried to analyse the pattern and correlation between different time series. Such analysis is called association rule mining (ARM) and it is also known as Market Basket Analysis and Affinity Analysis. This paper also tries to investigate the different lag among various different time series.

■ MB-60
Monday, 10:30-12:00 - Graham Hills GH813, Level 8

Inventory Routing

Stream: Routing I - Models and Methods
Invited session
Chair: *Michele Quattrone*
Chair: *Luca Bertazzi*

1 - A Column Generation Framework for Industrial Gas Inventory Routing
Jean André, Rodrigue Fokouop, Michele Quattrone, Mehdi Lamiri, Emiliano Traversi, Roberto Wolfler-Calvo, Lucas Létocart, Roberto Baldacci

In this work we propose a column generation approach for solving the Inventory Routing Problem with Replenishment Facilities (IRPRF). The IRP concerns the distribution of liquefied industrial gases from a set of production plants to a set of geographically dispersed customers under Vendor Managed Inventory (VMI) distribution policy. The considered problem includes a rich set of business constraints from rules related to drivers working time through time windows for access restrictions to customers and production plants. The first version of the problem consists on minimizing a linear criterion representing the total distribution cost while, in the second version the criterion to minimize is non-linear (called logistic ratio). While both objective functions are common in practical application, only the first one has been studied deeply in practice and very few papers deal with the rational objective function. In this paper we propose a unified column generation approach that can solve both versions of the problem. The master problem (a set partitioning problem) will select a subset of feasible routes while insuring global constraints such as no product run-out at customer site, inventory capacity constraints... The pricing problem is modeled as a resources constrained shortest path problem and produces feasible routes that respects all shift related constraints. The paper provides preliminary computational results, based on real on the field instances.

2 - The Put-Away Problem in Parallel-Aisle Warehouses
Melih Çelik, Claudia Archetti, Haldun Sural

In warehouses, put-away operations involve the replenishment of capacitated item slots in forward storage areas from reserve storage. These items are later picked from these slots as their demand arises. While order picking constitutes the majority of warehouse operating costs, put-away operations might be as costly in warehouses where pick lists generally consist of only a few lines (e.g., order fulfillment warehouses).

In this study, we consider the put-away problem in a parallel-aisle warehouse, where put-away and order picking operations are carried out in successive waves with time limits. The aim is to determine the item slots that will be replenished and the route of the put-away worker in each put-away wave, so as to minimize the total labor and travel costs, and ensure the availability of items at the start of the wave they will be picked. The problem is analogous to the inventory routing problem due to the inherent trade-off between labor and travel costs.

We present complexity results on different variants of the put-away problem and show that the problem is NP-hard in general. Consequently, we develop a number of heuristic approaches. We test and compare the performances of these heuristics on randomly generated warehouse instances, and further analyze the effect of different storage policies (random, turnover-based, or class-based) and demand patterns (e.g., highly skewed or uniform).

3 - Integrated Solution Approach for an Inventory Routing Problem
Ali Ekici, Okan Ozener

We consider an inventory routing problem where a common vendor is responsible for replenishing the inventories of several customers over a planning horizon. Objective of the vendor is to minimize the total transportation cost while avoiding stock-outs at the customer locations. We propose an integrated clustering and routing algorithm to solve the problem in two stages.

■ MB-61
Monday, 10:30-12:00 - Graham Hills GH816, Level 8

Dynamic Programming 2

Stream: Dynamic Programming
Invited session
Chair: *Kai Helge Becker*

1 - Managing invasive species under structural uncertainty using partially observable Markov decision processes
Martin Peron, Kai Helge Becker, Iadine Chades

Aedes albopictus is a worldwide invasive mosquito that vectors debilitating diseases to humans. It has invaded the Torres Straits Islands, an Australian archipelago situated between Papua New Guinea and mainland Australia. The problem consists in preventing the mosquito from colonising mainland Australia under a limited budget. At each time step and on each island, managers can choose among three actions. In our talk, this sequential decision problem will be modelled, in a first step, as a Markov decision process (MDP). The states depict the invasion status of each island and the transition function captures the efficiencies of actions and the dispersal of the mosquitoes. However, the transition function is not known perfectly (structural uncertainty). It will be demonstrated that solving the MDP for different possible transition functions leads to significantly different optimal policies resulting in earlier or later infection of the Australian mainland. In a second step, we model the problem as a partially observable MDPs (POMDPs) in which each state is the combination of a system state and a model state, where the model state represents our current knowledge of the transition function. This approach achieves a trade-off between informative and rewarding decisions, i.e. between decisions that mainly improve our knowledge about the transition function and decisions that effectively delay the infection of mainland Australia. First computational results will be presented.

2 - Dynamic programming for combinatorial auctions with items arranged in rows

Bart Vangerven, Dries Goossens, Frits Spieksma

In combinatorial auctions (CAs), bidders place bids on combinations of items (packages). CAs allow bidders to better express their preferences compared to traditional auction formats, where bidders place bids on individual items only. The principal motivation for using CAs is the presence of complementarities or substitution effects, which can differ among the bidders. CAs have been used for applications varying from the procurement of freight transportation services (Ledyard et al., 2002), to bus routes (Kennedy, 1995) and allocating spectrum rights (McMillan, 1994). We consider an auction of similar goods that can be arranged in rows. An application of this setting is the selling of tickets for seats in a grandstand or stadium. Another application is selling pieces of land. Bidders can submit bids, but the subset of the goods they place a bid on has to be connected. Of course every good can only be sold once. The objective is to solve the winner determination problem (WDP). In general, the WDP is NP-hard. However, our problem has a geometric-based structure. Rothkopf et al. (1998) find this problem to be in P when the goods are arranged in 1 row and NP-hard for n rows. Goossens et al. (2014) found it remains in P for 2 rows. Our contribution is a dynamic programming algorithm which proves that the case of 3 rows is still in P. We also have a DP which works for any number of rows and a particular class of bids.

3 - Identifying steady-state in discrete event simulations of queuing networks

Philip Brabazon, Sajid Siraj

This study analyses a simulation of a queuing network as a dynamical system, an approach which leads to novel ways of solving the warmup problem. When analysing non-terminating simulation models it is often necessary to allow these models to reach steady-state and for the initial warm-up period to be discarded to avoid bias in the estimates of output metrics. Determining how much data to discard is the warm-up problem. We propose new techniques which are inspired by treating the simulation model as a dynamical system. A phase diagram of simulation output, in which the rate of change of a metric is plotted against the value of the metric, reveals the dynamic function for the metric. If the queuing network can reach steady-state, the dynamic function will have at least one attractor. We present a method for converting typical time series output from a discrete event simulation of a queuing network into a phase plot. We then describe several ways of using the phase plot to solve the warm-up problem.

■ MB-62

Monday, 10:30-12:00 - Livingstone LT203, Level 2

Operations Research 2

Stream: Operations Research, other
Contributed session
Chair: *Esmael Kakavand*

1 - Adaptive control of a tailless aircraft

Esmael Kakavand, M. Navabi

A combined model reference adaptive controller is developed for the approach and landing phases of an unstable multi-input multi-output tailless aircraft. In this type of model reference adaptive controller, the prediction error is added to the tracking error. The addition of the prediction error to the tracking error causes the improvements of the characteristics of the controller. A tailless aircraft has coupled and unstable behavior due to the lack of empennage components, especially in the lateral-directional channel. Hence, two separate controllers are designed to control both longitudinal and lateral-directional motions through the terminal phases. Simulations have been done in the presence of matched uncertainties and demonstrate the effectiveness of both controllers in making the aircraft stable.

2 - Optimization of LPG Supply Chain network using multi-objective Location Routing Problem

Pourya Pourhejazy, Oh Kyoung Kwon

Due to environmental concerns, Liquefied Petroleum Gas (LPG) has recently become one of the major fuels in developed countries. The LPG price is hugely dependent on the logistics costs. Although the location planning of fuel facilities and routing planning for its distribution system have been separately studied in several papers, they are interdependent and overall cost of the chain may be unwarranted if they are considered individually. The aim of this study is to propose a multi-objective LRP for the design of LPG supply chain network, and solve it using a meta-heuristic algorithm. Due to the importance of risk and green factors, simultaneous incorporation of externalities including air pollution, congestion, accidents, and noise pollution, and risk factors including transportation risk and facilities risk as the secondary objectives in LRP, is the main contribution that will be addressed in this study. The mathematical model has been tested on the LPG supply chain of a major South Korean LPG company. Results have proven an improvement in terms of risk and externalities compared with the one of current network.

3 - Crisis in Productivity in Tea Plantations of West Bengal: A Study with DEA

Tamash Ranjan Majumdar, Ajit Kumar Ray

Economic development of India depends largely on Tea production which constitutes a major share of export earnings. In recent times industry has been passing through a crisis of realizing higher level of productivity. Many have indicated that the existence of inefficiency in utilizing input resources may be one of the plausible reasons of declining productivity. Since various input factors influence the productivity of tea like labour, irrigation, drainage, garden size, replanting and rejuvenation etc, the measurement of efficiency of tea garden and optimal allocation of these resources may be helpful to understand the problem of declining productivity. Among several tea producing states in India, West Bengal holds a very prominent position and accounts for nearly 20 percent of the total area under tea plantation and contributes about 24 percent of the total production. The objective of the present study is to make an analysis based on secondary official data of 273 gardens of West Bengal in order to assess the relative effects of various productivity parameters on tea production and productivity so that the relative importance of each parameter could be better understood. We have also attempted to identify the causes of resource use inefficiency and declining productivity by applying DEA. This would help proper strategic planning and management of tea plantation.

■ MB-66

Monday, 10:30-12:00 - Livingstone LT209, Level 2

Convexity and applications 1

Stream: Optimization
Invited session
Chair: *Margarita Rodríguez Álvarez*

1 - Robust convex multi-objective programming

Miguel Goberna

In this talk we examine multi-objective convex programming problems in the face of data uncertainty both in the objective function and the constraints, allowing linear perturbations of the objectives and affine perturbations of the constraints. We present optimality conditions for minmax robust weakly efficient solutions, i.e., the weakly efficient solutions of the robust counterpart, and for highly robust weakly efficient solutions, i.e., robust feasible solutions which are weakly efficient for any possible instance of the objective matrix within a specified uncertainty set. We finally provide conditions guaranteeing the existence of the latter type of solutions (bounds for the radius of robust highly weak efficiency). The results presented in this talk, which is based on research in progress with V. Jeyakumar, G. Li, and J. Vicente-Pérez, generalize previous results on linear MOLP obtained by the same authors: M.A. Goberna, V. Jeyakumar, G. Li, J. Vicente-Pérez, Robust solutions to multi-objective linear programs with uncertain data, European J. Oper. Res. 242 (2015) 730-743.

2 - Stability in linear optimization under perturbations of the left hand side coefficients

Marco A. López-Cerdá

We present some new results in relation to the stability properties of linear optimization problems with finitely many variables and an arbitrary number of constraints, when only left hand side coefficients can be perturbed. The coefficients of the constraints are assumed to be continuous functions with respect to an index ranging on certain compact

Hausdorff topological space. More in detail, we analyze the continuity properties of the feasible set, the optimal set and the optimal value, as well as the preservation of desirable properties (boundednesss, uniqueness) of the feasible and of the optimal sets, under sufficiently small perturbations.

3 - Properties of e'-convex sets and e'-convex functions
Jose Vidal, Maria Dolores Fajardo

For a general optimization problem, where the objective function is defined on a locally convex separated topological space, applying the perturbational approach to duality for convex optimization problems and the c-conjugation theory, which is derived from generalized convex conjugation theory, we obtain a dual general problem in terms of the c-conjugate of the perturbation function. In the particular case where this function is evenly convex (e-convex, in brief), i.e. its epigraph is an e-convex set (the intersection of an arbitrary family of open half spaces), we can find a regularity condition for strong duality, what we have named e-convex optimality, between the primal and its dual problem written by means of the e'-convexity of the projection of a determined set. E'-convex sets form a subclass of the e-convex sets class, and are defined as arbitrary intersections of epigraphs of c'-elementary functions. Since e'-convexity plays an important role in e-convex optimality, it is necessary the study of the most important properties that e'-convex sets verify, and to analyze the properties of e'-convex functions, which are defined as those functions whose epigraph are e'-convex sets.

4 - Lagrange duality for evenly convex optimization problems
Margarita Rodríguez Álvarez, Maria Dolores Fajardo, Jose Vidal

An evenly convex function on a locally convex space is an extended real valued function whose epigraph is the intersection of a family of open halfspaces. In this paper, we consider an infinite dimensional optimization problem for which both objective function and constraints are evenly convex and we give a Lagrange-type dual problem for it. The aim of the paper is to establish regularity conditions for strong duality between both problems, formulated in terms of even convexity. The first condition we state can be viewed as a version of the so-called closed cone constrained qualification related to a convex optimization problem in the classical context. Another two conditions are derived as particular cases of two already existing regularity conditions which were obtained in a previous work. We finally compare the three regularity conditions.

■ MB-67
Monday, 10:30-12:00 - Livingstone LT210, Level 2

Valid Inequalities and MIP Reformulation

Stream: Combinatorial Optimization
Invited session
Chair: *Laura Galli*

1 - Four Separation Algorithms for the Simple Plant Location Problem
Adam Letchford, Laura Galli, Sebastian Miller

The Simple Plant Location Problem is a well-known (and NP-hard)combinatorial optimisation problem arising in logistics applications. The associated family of polyhedra has been studied in depth, and several families of facet-defining inequalities are known. On the other hand, very little attention has been paid to separation algorithms, i.e., algorithms for generating those inequalities when needed. To close this gap, we present four new polynomial-time separation algorithms, each of which separates over a family of valid inequalities that has an exponentially large number of facet-defining members.

2 - Natural Intersection Cuts for Mixed-Integer Linear Programs
Trivikram Dokka, Adam Letchford

Intersection cuts are a family of cutting planes for pure and mixed integer linear programs, developed in the 1970s. Most papers on them consider only cuts that come from so-called maximal lattice-point-free polyhedra. We define a completely different family of intersection cuts, called "natural". Their key property is that they can be generated very quickly and easily from a simplex tableau. In many cases, one can also easily strengthen them, using an idea of Balas and Jeroslow. We show that the strengthened cuts are a generalisation of Gomory mixed-integer cuts, and then show how to tailor the cuts to problems with special structure (such as knapsack, packing, covering and partitioning problems, or problems with complementarity constraints or fixed charges). We present some computational results to illustrate the use of the new cuts.

3 - Delay-Constrained Shortest Path: Scheduling Models and Admission Control
Laura Galli, Antonio Frangioni, Giovanni Stea

Recently, a new class of Delay-Constrained Shortest Path (DCSP) problems in computer networks has been introduced and it has been shown that the combination of general-purpose Mixed-Integer Second-Order Cone (MI-SOCP) tools and fast ad-hoc heuristics is capable of solving realistic instances. However, so far we were only considering one of the many classes of schedulers in use in today's systems, namely Strictly rate-proportional schedulers. Schedulers of this class have simple latency expressions. Furthermore, they have a desirable property in terms of admission control, meaning that it is possible to determine the admission of a flow by only comparing its required rate to the available rate at each traversed link, independently of the rates reserved by other flows along the same path. This also implies that each flow which has already been admitted will not violate its maximum delay as long as the capacity of the links along its path is not oversubscribed. Other classes of scheduling algorithms commonly found in current network systems produce delay formulas that are both more complex and may not share that nice property. In this paper we therefore extend the models to other classes of schedulers, showing that, despite the increase in complexity, the DCSP problem is still efficiently solvable, even when admission control is factored in, for realistic instances provided that the right "reformulation" choices are made.

4 - Off-Gas Power Generation Optimization Using Mixed Integer Linear Programming
Philip Venter, Fanie (SE) Terblanche, Martin van Eldik

Engineering plants have interlinked production processes' of which some may generate burnable off-gasses. Common practice is generating steam from these off-gasses and using excess steam for power generation. Unused off-gasses are burned to atmosphere, where the energy potential is nullified. This paper proposes a mixed integer linear programming model that, under specified conditions, optimizes power generation via efficient off-gas usage. Model inputs include predicted off-gas flows and plant steam usage over time, steam generation capacities and efficiencies. The primary decision variables are concerned with the operational status of each turbine over time taking into account the minimum and maximum allowable steam requirements for each turbine. Although the objective function will aim to keep all turbines operational, the available steam at any point in time may trigger some of the turbines to halt. A turbine may only be started if a, predetermined, continuous minimum time interval has elapsed just before startup. During this interval sufficient steam must have been available to have kept all running turbines operational, including the turbine/s to be started up. Empirical results are based on real world data and show the practical use of the model within a manufacturing context.

■ MB-69
Monday, 10:30-12:00 - Livingstone LT212, Level 2

Credit Risk Modelling for Micro, Small and Medium Companies

Stream: Business Analytics and Intelligent Optimization
Invited session
Chair: *Cristian Bravo*

1 - Predicting Default Risk under Different Payment Frequencies
Cristian Bravo, Mee Chi So, Lyn Thomas

Different payment strategies (other than monthly installments) arise naturally in lending to micro, small and medium companies. Due to market conditions, there are incentive for lenders to offer other frequencies, such as quarterly, biannual, or annual repayments. In this presentation we will study the characteristics of default for borrowers under these conditions for loans granted to borrowers that operate in the primary sector (agribusiness), where the conditions of crops and the seasonality of demand make granting loans with different conditions common. We study the impact in prediction of using the payment frequency as a regressor, as well as the structural differences in terms of variables present, accuracies, and behaviors, when constructing different models for borrowers subject to different payment frequencies.

The results show first that the payment frequency is a relevant predictor, even when controlling for other factors, and that there are complex differences in the behavior of default for these companies, which can be attributed to both intrinsic variables, and also to external factors.

2 - Personality of entrepreneurs: is there a connection with credit repayment behaviour?
Galina Andreeva, Dean Caire, Wendy Johnson

In developed countries the bulk of information used in credit scoring relates to previous credit history supplied by credit bureaux. For developing countries and microfinance institutions there is a need for alternative types of information, since credit bureaux may not exist or hold very poor data. Similar problems arise where young borrowers or small business start-ups do not have any previous history that can be analysed. Historically, a borrower's 'Character' has been considered as one of the fundamentals in credit risk assessment (3 Cs that also include Capacity and Collateral). Whilst the idea itself that psychological traits are related to credit repayment performance is not new, the studies attempting to link them are scarce due to the difficulty of obtaining credit performance data together with personality measures. This talk will summarise the literature related to personality and credit behaviour, and will present preliminary results of factor analysis and regression from a small pilot study conducted in South Africa on a sample of taxi owners.

3 - Spatial regression models for UK SMEs
Jake Ansell, Raffaella Calabrese, Galina Andreeva

It was noted that there was a different behaviour regionally for the development of the financial crisis in UK. Hence to gain a better understanding UK SMEs performance during the financial crisis, this paper proposes an extension from standard scoring models to take into account the spatial dimensions by using spatial econometrics models. We find that spatial effects alter the parameter estimates of risk determinants for both start-up SMEs and non-start-ups in different UK regions. Furthermore, the spatial component improves the predictive accuracy of credit scoring models.

4 - Modelling Neural Network for Predicting Company's Creditworthiness
Marijana Zekic-Susac, Adela Has

Artificial neural networks have shown their success in prediction, classification, and association type of problems. This paper aims to find an efficient neural network model for predicting company's creditworthiness by using company's financial ratios, size, number of employees and some additional predictors. The network topology was optimized by a cross-validation procedure, and various activation functions were tested such as sigmoid, tangent hyperbolic, and sine function. The selection of the best model was performed by taking into consideration the model error as well as its stability in a subsampling procedure. The best neural network accuracy was also compared to the accuracy of a classification tree model. A real data was used from a sample of Croatian companies, and the obtained results were compared to some previous research in this area. The model can serve as a support to investors, such as bankers, government institutions, and others that need an insight into company's creditworthiness.

■ MB-70

Monday, 10:30-12:00 - Livingstone LT303, Level 3

Machine Learning for Improved Optimisation

Stream: Data Science for Optimisation
Invited session
Chair: *Ender Özcan*

1 - A data mining approach to modelling the university timetabling problem
Johann Haraldsson, Thomas Philip Runarsson

The generic university timetabling problem and its solutions is typically not directly applicable to the real case. The practical problem of timetabling will typically have conditions unknown to the modeller or is too complex to address. There may numerous reasons for this and will be discussed.

Universities will have a history of hand made timetables from previous semesters from which it is possible to infer the preferred rooms for courses. How the courses are taught can also be extracted from these timetables. In addition, from student registrations it is possible to find clusters of courses typically taken by students. These clusters coincide with the typical curriculum, but many of them will define how students are actually taking their degree over a longer period. By looking at previous timetables and student registrations we will present a data mining approach to setting up realistic conditions for the university timetabling problem.

The case taken is that of the University of Iceland. We will create conditions that attempt to mimic previous timetables but still attempt to create flexibility in order to maximize the utilization of the scarce resource, the timeslots and classrooms, the best. A mathematical programming model will be presented for the data mined university timetabling problem and results presented.

2 - White box machinery supporting the development of heuristic algorithms
Patrick De Causmaecker

The domain of meta- and hyperheuristics has seen a rapid development. Metaheuristics offer versatile schemata supporting the development of heuristic algorithms for optimisation problems. Hyperheuristics introduce a domain barrier to hide incomprehensible details of solver architecture to domain experts providing low level heuristics. Vice versa, the same domain barrier shields specialists in algorithm construction from unnecessary domain dependent details. Both paradigma's introduced a form of generalization and bargained solution quality against development efficiency. Parameters introduced by such techniques make the algorithms sensitive to variations of these parameters and an optimal set of parameters can only be obtained for a specific distribution of problem instances. Parameter tuning tools have been developed that, in a black box setting, allow the tuning of parameters against instance sets. Automated algorithm construction uses a similar philosophy to construct algorithms for a given instance set. Presently not much support is available for developers in the course of the design of their algorithm, i.e. in a white box setting. In this talk, we will investigate instruments from statistics, mathematics and machine learning that could be set to use in a white box setting. Specific problems posed are strict requirements on response times that cannot be too long, incorporation and recognition of historic data collected in the current or earlier development processes.

3 - Gray box tuning of the VeRoLog solver
Nguyen Thi Thanh Dang

We report on a study of the parameter setting and the design decisions for the winning solver of the VeRoLog competition 2014. A defining characteristic of this solver was the large number of neighborhoods used in the local search based heuristic. This introduced many parameters which were set using machine learning during the development of the solver. Machine learning was switched of and the winning algorithm was a frozen version. Clearly this setting opens possibilities for generalization in the direction of developer guidance and support in the course of the development. We study and compare observables related to the neighborhoods such as improvement rate and acceptance rate. We present a statistical analysis of these quantities and their repercussion on the solution quality.

4 - Reinforced island model Genetic Algorithm for the University course timetabling problem
Alfian Gozali

University Course Timetabling Problem (UCTP) is a scheduling problem in assigning lecturing events into time and room dimension by considering several university stakeholders such as students, lecturers, and departments. There are many approaches to solve this problem either by soft or hard computing. Asynchronous Island Model Genetic Algorithm (Async IGA) is one of them. Despite of its great performance, Async IGA has a drawback; it fails to use its resources optimally. It could leave some idle machines while completing all of its

process. Reinforced Async IGA is a method to overcome this draw-back by optimizing resource usage of the machines. Reinforced Async IGA forced the machines which has finished its process to help other unfinished machines. This research shows that Reinforced Async IGA can improve both its time performance in computational execution process.

■ MB-71

Monday, 10:30-12:00 - Livingstone LT307, Level 3

Non-airline applications of revenue management

Stream: Revenue Management
Invited session
Chair: *Benoit Rottembourg*

1 - Dynamic Booking Control for Car Rental Revenue Management: A Decomposition Approach
Dong Li , Zhan Pang

Different from conventional airline revenue management, car rental revenue management needs to take into account not only the existing bookings but also the lengths of the existing rentals and the capacity flexibility, which yields high-dimensional system state space. In this work, we formulate a single-station booking control problem as a discrete-time stochastic dynamic program over an infinite horizon, which is computationally intractable due to the curse of dimensionality. We propose a decomposition approach to the development of two heuristics. The first heuristic is an approximate dynamic program (ADP) which approximates the value function using the value functions of the decomposed problems. The second heuristic is constructed directly from the optimal booking limits computed from the decomposed problems. Our numerical study suggests that the performances of both heuristics are close to optimum and significantly outperform a commonly used probabilistic non-linear programming (PNLP) heuristic in most of the instances. The dominant revenue performance of our second heuristic is evidenced in a case study using sample data from a major car rental company in the UK, which also sees higher fleet utilisation from our proposed policy. Our results further suggest that the PNLP heuristic is conservative in vehicle movements. It could be still suitable for situations with large demand and low shuttling cost. Otherwise, the proposed heuristic should always be the choice.

2 - Pricing for internet sales channels in car rentals
Beatriz Brito Oliveira, Maria Antónia Carravilla, José Fernando Oliveira

The car rental business model for leisure customers has been heavily impacted by the proliferation of internet brokers that compare prices in the market, mainly because the product/service is not significantly differentiated between competitors. Moreover, in this business, fleet occupation and idleness have a major impact on the costs, since the resources can be seen as perishable (a day's occupation cannot be filled further in the future). Considering that the e-brokers sales channel brings a high flexibility to change the prices, it is critical to manage the pricing of the reservations over time, seizing each customer's different willingness to pay, as in traditional revenue management problems. At the same time, however, this channel also brings the need to constantly monitor competitor's prices, since the customer "decision to buy' is now deeply connected with the positioning of the company's price on the market (if it is the lowest or not). This problem has been recently tackled in a Portuguese car rental company, who was in need of a system that allowed to frequently update and optimize the prices on the e-brokers' websites, considering not only fleet occupation and its levels of protection for higher-revenue customers but also the prices of the competitors in the market at the time. This problem is herein described, detailing its specificities and their implication on the applied solution design.

3 - Nonlinear Pricing Problem for Container Leasing
King-Wah Anthony Pang , Wen Jiao, Hong Yan

With the substantial upsurge of container traffic, the container leasing company thrives on the financial benefits and operations flexibility of leasing containers requested by carriers and shippers. In practice, container lease pricing problem is different from other commercial product pricing regarding the fair value of container, limited customer pool and

monopolistic market structure. In view of the durability of containers and the diversified lease time and quantity, pricing is a challenging task for the leasing company. Therefore this study examines the monopolist's nonlinear pricing problems. In particular, the leasing company designs and commits a price menu and hire quantity (time) pairs to maximize the expected profit and in turn customers choose their hire quantities (time) to maximize their surpluses depend on their hire time (quantity) preferences. We obtain the closed-form solutions for one group of customers and mixed groups of customers under capacity constraint in static environment. In the dynamic environment, we restrict our study to two customer types and derive closed-form solutions where customers have the preferred hire time.

4 - Allotment Optimisation Strategies for Camping Revenue Management
Benoit Rottembourg

In the hospitality industry, an allotment is a block of pre-negotiated "rooms' which have been bought by a tour operator. In the context of campsites, allotments represent a significant share of the mobile homes sales. Once the tour operator has contracted the allotement its role is to resell the mobile home weeks to final customers.

For the campsite owner, dealing with tour operator allotment requests is a poisoned chalice. On one hand these pre-booked sales are more or less a guarantee of selling a good share of its inventory. On the other hand, the discount level is so high that selling the whole inventory through allotments could potentially ruin the business. Hence, a balance must be found between allotment contracts and estimated direct sales to final customers (at full price, or lightly discounted price).

The purpose of our presentation is to show that the stochastic optimisation problem with recourse at stake is highly combinatorial and that algorithmic approaches relying on continuous relaxations of the demand behave poorly. For multi-site allotment optimisation with service level requirements from tour operators, we developped a Lagrange decomposition technique based on local Markov Decision Process solvers that outperforms classic "fluid displacement" approaches. We will provide experimental results on instances with 200 campsites 20000 mobile homes and 15 tour operators inspired from a leading european actor of the campsite industry.

■ MB-72

Monday, 10:30-12:00 - Livingstone LT311, Level 3

Boolean Methods and Binary Optimization

Stream: Boolean and Pseudo-Boolean Optimization
Invited session
Chair: *Endre Boros*

1 - Improved Exact Resolution of Multi-Constrained Path Problem
Walid Khallef , Miklos Molnar, Sylvain Durand

Several challenging issues exist in Quality of Service (QoS) provisioning in networks, and the QoS constrained routing is one of the most important issues. The QoS routing from a source to a destination leads to the well known multi-constrained path problem (MCP). The objective of MCP is to find a feasible path with respect to a set of QoS constraints. Since this problem is NP-complete, the solutions proposed in the literature are either time-consuming, or do not guarantee to find a solution even if the problem is feasible. Some of the most efficient algorithms proposed by Kuipers and al. are SAMCRA for the exact resolution and TAMCRA for the approximation. Based on the same ideas (using a Dijkstra-like search with a non-linear function and a reduction of the space search by non-dominance principle), we propose an exact algorithm, that manipulates the constraints to improve significantly the computation time. For hard instances, the results are similar to SAMCRA, but for easier instances, reinforcing the constraints leads to reduce the space search with a high probability of finding a solution. In some cases the algorithm memorized 40% less non-dominated paths than SAMCRA. We then show how, in QoS constrained multicasting cases, the solution can be applied to compute flexible multicast routes corresponding to hierarchies.

2 - Constant-time tester on a natural class of scale-free multigraphs
Hiro Ito

Nowadays developing efficient algorithms for treating big data is an urgent task. We consider constant-time testability of properties on scale-free networks. A graph property is a (possibly infinite) family of graphs, which is closed under isomorphism. A a tester for a property accepts an input graph if it has the property and rejects it if it's far from having the property in high probability (e.g., at least 2/3) by reading a constant part of the input. A property is said to be testable if there is a tester. We introduce a natural class of (multi)graphs, Hierarchical Scale-Free Multigraphs (HSF, in short) for modeling real scale-free networks, and consider constant-time testability on the class. We first show that multigraphs in HSF is hyperfinite. For positive real numbers t and eps, a graph consisting of n vertices is (t,eps)-hyperfinite if one can remove at most eps n edges from the graph and obtained a graph whose connected components have size at most t. It has been known that every property is testable on the class of hyperfinete graphs with degreee bounded by a constant by Newman and Sohler in STOC11. While HSF is not degreee bounded by a constant, we can also construct a universal tester for HSF by using the hyperfineteness, i.e., we get the following result: Every property on the class of scale-free multi-graphs is testable. This is the first universal result of constant-time testability on sparse graphs with no degree upper bound.

■ MB-73

Monday, 10:30-12:00 - Collins CL205, Level 2

Forecast Optimisation and Error Measurement

Stream: Forecasting & Time Series Prediction
Invited session
Chair: *Chris Tofallis*

1 - Trace likelihood and shrinkage in estimation of the forecasting models
Ivan Svetunkov, Nikolaos Kourentzes

The standard approach for estimating forecasting models is usually based on the likelihood function using one-step-ahead forecasting error. But several empirical studies have shown over the years that minimizing the sum of squared errors for multiple steps-ahead forecasts may lead to more accurate parameters estimation. Although it is intuitive that aligning the forecasting objective with the optimisation cost function is beneficial, we propose a statistically justified theoretical rationale to do this. We also demonstrate the difference between the traditional multi-steps-ahead objective function and the objective function obtained from the proposed trace likelihood function. In addition it has been argued in the literature that in the absence of a true model, it is preferable to use an extended likelihood, using multiple steps-ahead forecast error. We extend this finding by proving that maximising multi-steps-ahead likelihood is equivalent to single-step-ahead optimisation with parameter shrinkage. Therefore, maximising the proposed likelihood both incorporates the forecasting objective in the estimation and overcomes estimation limitations due to sampling or model form. We validate our theoretical findings by conducting experiments on real data and showing the advantage of the proposed approach in comparison to the standard likelihood function maximization.

2 - Symmetrical drawback of relative errors in extreme scenarios forecasting
Antonio Boada, Ivelis Montilla, Laura Cardoza

This article intends to explain the symmetrical drawbacks that could be found in relative frequency as well as relative percentages when doing company sales forecast under extreme scenarios (Lind, 2005). The absent of symmetry in relative percentage indicators that are, currently, used in sales forecast originates a lack of equity when figuring out certain 'a posteriori estimation. As a consequence, this generates a limitation on the statistical formulation when the random variable (Future sales VF) presents a limited influence on the positive real numbers (R+). Through a statistical verification of the relative error formula which has been reduced to the positive real numbers, it could be verified that when 'a posteriori' demand (DP) exceeds the estimated units more than twice (2VF), there is not symmetrical contraposition of its percentage value; thus, it shows an absence of indicator equity of the

Key Performance Indicators (KPI) gestion. Hence, the KPI, which is used in sales forecast as a relative error, shows strength of symmetrical consistence until the average of 'a posteriori' demand (DP) do not exceed the doble of the estimated units (2VF). In extreme scenarios, such as the demand tendency of Latin American markets, for instance, where DP exceeds 2VF, it was found that the use of typified values, or the demand segmented analysis, could provide better KPIs in Estimation Departments.

3 - A better measure of relative prediction accuracy for model selection and model estimation
Chris Tofallis

Surveys show that the mean absolute percentage error (MAPE) is the most widely used measure of prediction accuracy in businesses and organizations. It is, however, biased: when used to select among competing prediction methods it systematically selects those whose predictions are too low. This has not been widely discussed and so is not generally known among practitioners. We explain why this happens. We investigate an alternative relative accuracy measure which avoids this bias: the log of the accuracy ratio, that is, log (prediction/actual). Relative accuracy is particularly relevant if the scatter in the data grows as the value of the variable grows (heteroscedasticity). We demonstrate using simulations that for heteroscedastic data (modelled by a multiplicative error factor) the proposed metric is far superior to MAPE for model selection. Another use for accuracy measures is in fitting parameters to prediction models. Minimum MAPE models do not predict a simple statistic and so theoretical analysis is limited. We prove that when the proposed metric is used instead, the resulting least squares regression model predicts the geometric mean. This important property allows its theoretical properties to be understood.

■ MB-77

Monday, 10:30-12:00 - Collins Insight Institute

Behavioural issues in forecasting

Stream: Behavioural Operational Research
Invited session
Chair: *Fotios Petropoulos*

1 - Forecasting for a simultaneous regular and non-regular production planning of multipurpose batch plants: a behavioural operations perspective in a Pharmaceutical company
Konstantinos Nikolopoulos, Christina Phillips

In this study we are discussing a real case study from a Pharmaceutical company and in specific production planning of a multipurpose batch plant in Europe; involving simultaneously both regular and non-regular production scheduling dominated by uncertain demand for both aforementioned processes. At the moment the organisation shifts towards a leaner approach considering levelling and balancing the production of the more regular part of the demand and production - typically the class A products, but the transition remains to be initiated assuming favourable results from a series of in-house simulation studies. We particularly focus on the forecasting function in the plant and the modelling of the behavioural aspects of it.

2 - Cross-cultural differences in judgmental forecasting
Xia Meng

Previous research has established that: i) judgmental prediction intervals tend to be too narrow for the stated coverage probability, showing that people exhibit overconfidence; ii) mis-calibration is common in probability forecasting (i.e. subjective probabilities tend not match the true probabilities); iii) judgments can be sensitive to different frames in forecasting tasks (e.g. whereas overconfidence is revealed in judgmental prediction intervals, underconfidence is found in probability judgments); iv) a cross-cultural difference exists in general knowledge probability judgments (overconfidence is much higher when people have a Chinese, rather than a Western, cultural background). This paper reports on two experiments that were designed to examine whether Chinese people exhibit different levels of overconfidence compared to Western people, in judgmental forecasting when they are asked to make either probability or interval forecasts . A follow-up survey assessed whether any differences could be explained by a lack of familiarity with probabilistic thinking among Chinese people.

3 - Allowing for promotion effects in judgmental forecasting: Effects of series type and provision of formal forecasts

Shari De Baets, *Nigel Harvey*

While statistical forecasting methods can generate predictions based on the logical and systematic processing of information (Goodwin & Wright, 2010), they have difficulties with discontinuities, unexpected events and external influences (Armstrong & Collopy, 1998; Goodwin, 2002). This study examines how forecasters perform in predicting sales numbers when the time series are subject to occasional promotional events (Goodwin & Fildes, 1999). This was investigated in a series of experiments by varying within experiments (a) difficulty of the time series: independent versus autoregressive (AR(1)), (b) presence of a statistical forecast and forecast history, and across experiments: (c) feedback and (d) the relationship between the promotional expenditure and the effect on sales. Experiment 1 (linear relationship, no feedback) indicates that forecasts are too low when promotions are present and too high without promotions, suggesting an anchoring effect on the mean of the series. This effect increases with the presence of a statistical forecast. Experiment 2 (S-shaped relationship, no feedback) generally confirms Experiment 1 but also shows that forecasters linearize the promotions-effect relationship when asked to graph it. Two additional experiments are currently being run: one investigating the effect of providing immediate outcome feedback and one on the effect of providing explicit information about the relationship between the promotional expenditure and sales increase.

4 - DIY forecasting: judgment, models and judgmental model selection

Fotios Petropoulos, *Nikolaos Kourentzes*, *Konstantinos Nikolopoulos*

In this paper we explore how judgment can be used to improve model selection for forecasting. We investigate the performance of various judgmental model selection methodologies against the benchmark statistical one, based on information criteria. Apart from the simple model choice approach, we examine the efficacy of a model build approach, where experts are asked to identify the structural components (trend and seasonality) of the time series. Based on a large sample of almost 700 participants that contributed in a custom-designed laboratory experiment, we evaluate the performance of individuals and groups of experts in terms of selecting the best model and forecasting performance, identifying major improvements. Finally, we examine how to extend statistical model selection to incorporate additional insights from experts.

■ MB-78

Monday, 10:30-12:00 - Architecture AR201, Level 2

Practical Operational Research in Healthcare 2

Stream: Practical Operational Research in Healthcare
Invited session
Chair: *Phillip Worrall*

1 - Outcomes based, whole-system commissioning for obesity and weight management; modeling and simulation challenges

David Gilding

An estimated 67% of English adult males and 57% of adult females are obese or overweight (body mass index — BMI - of more than 25kg/m2). This case study reports on modeling and simulation work carried out in Nottinghamshire County, England to support the commissioning of a whole system pathway to prevent, treat and support overweight and obesity for the whole population aged 5 years and older. An estimated 257,000 men, women and children were eligible for these services across the County.

Key modeling and simulation challenges included: ● construction of a conceptual model of a treatment pathway that incorporated commissioning responsibilities of three national and local Government from the National Health Service and local authority bodies and followed national guidance from NICE (National Institute for Health and Care Excellence); ● methods to estimate numbers with increased health risk

as a result of overweight, increased waist circumference or comorbidity; ● how to construct an outcomes based contracting and payment model based on individual health gain; ● determination of client flows and expected whole-system temporal demand, given that some patients could expect treatment for a few weeks, others for up to three years.

2 - Cleaning process in Operating rooms - Simulation based analysis of the Central-Operating-Rooms of a University Hospital

Olav Goetz, *Maria Zach*, *Maria Riemann*, *Steffen Fleßa*

Background: The operating rooms are one of the most expensive areas in hospitals. Operations research offers a variety of tools that may support the presentation and evaluation of processes. Especially, Discrete Event Simulation (DES) represents a method to support these analyses.

Material and Methods: Based on empirical data, gathered by observation, interviews, process analysis, time study and data from the hospital information system, the study examines the treatment process including the cleaning processes in the Central-Operating-Rooms (COR). By using a stochastic DES model, we modeled the treatment process within the COR. After verifying and validating the model, we analyzed the effects of changes by including scenarios with a special focus on different personnel policies for the cleaning process.

Results: The results of the study show that DES is an appropriate method for representing the operational processes within the COR. In addition, by simulating several scenarios, it is possible to investigate effects of process changes. Especially, using a varying number of cleaning personnel leads to a changing average of cleaning time and to a change in the possible number of patients treated.

Conclusion: We conclude that DES is a powerful tool that can substantially support the areas of process management, thereby helps to reduce costs, improve the planning and increases the efficiency of OR-processes in hospitals.

3 - Robust and dynamic kíndey exchange program optimization models

William J. Guerrero

This paper presents a mathematical formulation for the allocation decisions for a kidney exchange program. The problem considers a set of patients suffering from advanced stages of chronic kidney disease. These patients require a kidney transplant which increases their life expectancy up to 10 years.

In Colombia, around 800,000 people suffer from the disease and 25,000 are registered in waiting lists for kidneys, but only less than 1000 transplants are performed yearly. Further, this disease represents important financial and social costs to the country's healthcare system.

When applying to the exchange program, the patient informs of a relative or friend willing to donate a kidney. A direct transplant between the two of them is not possible due to incompatibility of antigens. Then, by donating a kidney, the diseased patient will receive a kidney in exchange for the donated one.

Then, the decisions to be optimized are the set of couples that are admitted into the exchange program and the transplants to perform in order to maximize the general benefit for patients. Also, a new constraint into the model is included in order to propose a robust solution: it is proposed that no more than a constant B of patients are forced to be excluded from the solution when specific transplants fail to be performed. Current research includes a study on dynamic re-optimization of transplant decisions, and efficient heuristics for the studied problems.

4 - A mathematical modelling approach to determine time and volume based purchasing commitments in long-term care

Phillip Worrall, *Thierry Chaussalet*

Long-term care (LTC) includes the range of services and treatment options provided to those with chronic or mental illness or physical disability. The responsibility for both funding and organising LTC rests with local authorities (LA) and NHS commissioning organisations. Historically, NHS organisations purchased care through a mixture of block con-tract (BC) and spot contract (SC) arrangements. Under a BC, NHS organisations purchase a fixed capacity of care from one or more care home providers for a fixed length of time. In contrast, SC are one-off purchases of care that involve no long- term commitment and are subject to periodic review. As individuals requiring NHS funded LTC come forward they are assigned to either an existing BC or a newly established SC. We propose a mathematical programming formulation of the decision facing LTC NHS commissioners. We consider a case where by commissioners must decide how to allocate resources to each provider in a local LTC market so as to satisfy demand. Commissioners, by making a commitment, are able to secure their supply

of LTC places over a planning horizon, whilst simultaneously securing volume and time-based discounts. In our model, each provider submits a discount regime based on different commitment volumes together with the standard, non-discounted, SC price. In contrast to previous work in this area we allow for contracts to slide such that they may start and end in subset of the planning period.

■ MB-79

Monday, 10:30-12:00 - Architecture AR310, Level 3

OR for Public Health II

Stream: Operational Research for Public Health
Invited session
Chair: Christine Currie
Chair: Honora Smith

1 - A Simulation-Optimisation Model for Production Planning in the Blood Supply Chain
Andres Felipe Osorio, Sally Brailsford, Honora Smith

Production planning in the blood supply chain is a complex task. Multiple aspects such as proportionalities of blood groups, shelf life constraints, multiple collection and fractionation alternatives and capacity constraints must be considered. This complexity requires advanced decision-making methodologies. This article presents an integrated simulation-optimisation model to support decisions in production planning. The simulation model is used to represent the flows throughout the supply chain considering collection, production, storing and distribution. On the other hand, an integer linear optimization model running over a rolling horizon planning scheme is proposed to support daily decisions about number of donors required, including blood groups, collection and fractionation methods. The integration of simulation and optimization methodologies enhance the decisions making processes in the studied system. The proposed methodology is evaluated using real information from a blood centre in Colombia. Results show that applying the developed rolling horizon optimization model, a reduction of 12%, 21% and 100% is obtained in the stockout rate for red blood cells, platelets and plasma and cryoprecipitate respectively. In addition, the expired number of units is also reduced by 95% for red blood cells and 36% in the case of platelets. Finally, the number of donors required and the production cost are reduced by about 2.2% using the optimization model proposed.

2 - A Simulation Model of Long-Term Survival Estimates and Economic Costs of Antiretroviral Therapy (ART) in Zambia
Christine Currie, E Mushota Kabaso, Sally Brailsford

Zambia has over 1.9 million people living with HIV and is one of the countries hardest hit by the HIV pandemic in sub-Saharan Africa. Limited information exists on the long-term survival and economic costs of the provision of antiretroviral therapy (ART) in the country. The study we describe here has two aims: 1. Provide better estimates for the long-term survival of people on ART; 2. Forecast the number of people on ART and the cost of providing ART in Zambia over the next decade. Survival analysis techniques have been used to estimate distributions for the time spent on ART using electronic records from the Zambian national database. This also allowed us to determine which sub-populations should be included in the simulation model. We use Discrete Event Simulation to model the number of people on ART in Zambia and provide projections for the cost of providing ART in the future. HIV-infected patients enter the model when they commence ART and then change their health states stochastically until they exit the system due to death, becoming lost to follow up or stopping treatment. Costs are calculated from the public sector perspective and we anticipate the tool being used for planning purposes in Zambia.

3 - Availability of HIV/AIDS Testing Facilities: Case Study in South Africa
Honora Smith, Maria Battarra

The availability of timely, accurate laboratory diagnostic tests for illnesses is important for public health in a region. We consider the problem of the location of diagnostic laboratories for HIV/AIDS testing, where several tests may be ordered by hospitals or other medical facilities. The tests involved, CD4, HIV viral load and Infant PCR, are required at widely varying frequencies: CD4 testing is required for all new HIV/AIDS patients, while Infant PCR is needed only rarely for infants. The design of a network of laboratories for efficient location of appropriate capacity test equipment is therefore of critical importance for test results to be returned promptly to patients while keeping costs low. We apply Mixed Integer Programming to this location problem in a hub-and-spoke network for hierarchical-destination tests. The model is applied in a case study in South Africa, where the National Health Laboratory Service operates testing facilities nationwide. Results for different scenarios demonstrate trade-offs between reduction of numbers of test laboratories and reduction of transportation costs.

■ MB-80

Monday, 10:30-12:00 - Architecture AR311, Level 3

Ecological Aspects of Transportation Planning

Stream: Transportation Planning
Invited session
Chair: Frank Schultmann
Chair: Yannis Marinakis

1 - A bi-objective intermodal transportation planning problem for large-scale distribution networks
Thomas Kirschstein, Christian Bierwirth, Frank Meisel

We present a model and solution approach for intermodal transportation planning in a supply network considering cost and total emissions to be minimized. The model includes relevant decisions regarding cargo consolidation at intermodal terminals and capacity bookings for road and rail transports. A mesoscopic emission model is applied to estimate the emissions of road and rail transports. For the resulting bi-objective MILP a Branch-and-Cut approach and a heuristic solution procedure is designed. The heuristic relies on a problem decomposition and shows convincing results with respect to running time and solution quality. A comprehensive case study for a chemical company illustrates the applicability of both solution methods to a real world problem instance. For the case study problem cost saving potentials of intermodal solutions over pure road transport solutions can be identified. At the same time, companies are supported in quantifying the trade-off between total cost and total emissions such that a sound basis for calculating emission avoidance cost in distribution planning is provided.

2 - Dynamic pricing of delivery services to minimize CO2 emission from vehicles
Yizi Zhou, Rupal Rana, Jiyin Liu

Companies delivering services directly to customers have been under increasing pressure by regulations to reduce CO2 emissions from delivery vehicles recently.Meanwhile maximizing profit remains a main objective for these companies.The demands for such services are usually unpredictable and come with preferred delivery time windows.We study a problem where a company sends employees with vehicles to customer sites to provide services.Customers call for services with preferred time periods and the company will schedule the service tasks and decide the vehicle routes.There has been research focusing on constructing vehicle routines with low emission, but it is found that minimizing emission often conflict with maximizing profit. We propose a new approach to this which applies both low-emission vehicle routing techniques and scheduling techniques with dynamic pricing to reduce CO2 emissions and to maximize profit.Upon receiving a call from a customer with preferred service time period,the company will provide the customer a few service time options and the corresponding prices.Incentives are included in the prices to influence the customer's choice so as to reduce CO2 emission.To help the company determining the incentives, we solves the problem in two phases.The first phase solves vehicle routing models with the objective of minimizing CO2 emissions and the second phase solves a dynamic pricing model to maximize profit.The approach is tested through computational experiments.

■ MB-82

Monday, 10:30-12:00 - Architecture AR401b, Level 4

Stochastic and Mathematical Programming in Health Care

Stream: Healthcare Service Improvement
Invited session
Chair: *Gil Luís*

1 - A Mathematical Programming Approach to Multi-Way Kidney Transplantation

Fatma Kutlu, Sibel Girgin, Fadime Üney-Yüksektepe, Tülin Aktin

Kidney exchange has becoming a very common and important treatment alternative for patients suffering from serious kidney diseases with incompatible donors. In a kidney exchange, important factors such as blood type, HLA matches, gender, age and PRA existence are considered to determine the compatibility. In a two-way swap, two incompatible patient-donor pairs exchange their donors who are compatible with the other recipient. More generally, n incompatible patient-donor pairs can have a multi-way exchange. As the number of swaps increases, the number of patients who get a healthy kidney will consequently increase. Therefore, there exists a need for an analytical approach that will determine the best n-way exchange.

In this project, a mathematical model will be developed for multi-way kidney exchange problem where the length of the exchanges will be controlled. The optimal solution of the proposed model will be obtained by using GAMS software and CPLEX solver. Moreover, different scenario analysis will be performed to measure the impact of "gender differences' and "age' on the solutions. Thus, the patients will be efficiently assigned to an n-way swap and their health condition will improve.

2 - Diet models with linear Goal Programming: impact of achievement functions

J.c. Gerdessen, Jeanne H.M. de Vries

With expected global population increase coupled with concerns about food security efficient use of food becomes ever more important. Both obesity and malnutrition are cause for concern. The result is a series of complex and challenging nutrition problems. Diet models help to identify solutions to such problems. Diet models based on goal programming (GP) are valuable tools for designing diets that comply with nutritional, palatability and cost constraints. Results derived from GP models are usually very sensitive to the type of achievement function that is chosen. We demonstrate several achievement functions on a diet problem with 144 foods, 19 nutrients, and several types of palatability constraints, in which the nutritional constraints are modelled with fuzzy sets. MinSum achievement functions can give rise to solutions that are sensitive to weight changes, and that pile all unwanted deviations on a limited number of nutritional constraints. MinMax achievement functions spread the unwanted deviations as evenly as possible, but may create many (small) deviations. Extended GP comprises both types of achievement functions, as well as compromises between them. It can thus, from one dataset, find a range of solutions with various properties. This study provides important insights for decision-makers in diet modelling and public health.

3 - A Stochastic Programming Approach for Optimizing Cryoprecipitate Collection Schedules

Beste Basciftci, Z. Caner Taşkın, Turgay Ayer, Chelsea (Chip) C. White III

In this study, we investigate the problem of generating weekly collection schedules for cryoprecipitate, a vital blood product as the main source of fibrinogen. As cryoprecipitate requires special equipment for collection, a two-day notice is needed before a blood collection visit can be assigned to cryoprecipitate collection. Due to the perishable nature of cryoprecipitate, we consider its eight hours collection to completion time constraint, in addition to the daily processing capacity of host sites. We aim to minimize the total collection cost while determining which blood collection visits should be assigned as cryoprecipitate collection visits to satisfy the weekly collection targets. We formulate the problem as an integer programming problem and propose a stochastic programming approach to model the uncertain nature of blood supplies. We investigate two different approaches in which the first one focuses on feasibility by meeting the weekly demand with a certain probability, and the second approach targets minimizing the expected penalty due to the unsatisfied demand.

4 - Evaluating policies with the highest potential to improve health and reduce health inequities in Europe through multicriteria resource allocation

Gil Luís, Monica Oliveira, Carlos Bana e Costa, Teresa Cardoso, Paulo Nicola

Multicriteria-based health indices have been developed to measure population health at different geographical levels, including to evaluate the health of the population in Portuguese municipalities and in US regions. There is virtually no literature on methods to evaluate which combinations of policies maximize a comprehensive population health construct and reduce different types of health inequities. Departing from information on a set of policies and on the impact of policies in a population health index, this study develops multicriteria resource allocation approaches to analyze which combination of policies maximize health and health equity in multiple dimensions for a set of geographical regions. The first step was to structure the multiple objectives that may be pursued by policy-makers (e.g. including the maximization of population health gains, the convergence towards a minimal level of population health across all regions, etc). The second step was to design alternative multicriteria resource allocation models to select the policies with the highest potential to contribute to those objectives and for a given level of cost or doability. These approaches are implemented in GAMS and in the resource allocation module of M-MACBETH. The models are applied to data from the GeoHealthS project. This study is being developed under the scope of the EURO-HEALTHY project, an EU project with the aim of "Shaping European policies to promote HEALTH equitY'.

■ MB-84

Monday, 10:30-12:00 - Architecture AR403, Level 4

Algorithms for Medical Problems

Stream: Computational Biology, Bioinformatics and Medicine
Invited session
Chair: *John Bowers*
Chair: *Farshid Jamali*

1 - Interactive Visualization and Analysis of Molecular Interaction Networks on the Example of Parkinson's Disease.

Piotr Gawron, Marek Ostaszewski, Reinhard Schneider

Our knowledge of disease-related molecular mechanisms grows rapidly. Organizing this abundant, domain-specific expert knowledge is a challenging task. Proper data visualization and analysis interfaces are required for efficient usage of this knowledge for exploratory or didactic purposes. We present a platform for visualization and analysis of complex molecular networks using web-based interfaces. Molecular mechanisms are represented as heterogeneous graphs, integrating resources like protein-protein interaction, gene regulatory or metabolic networks. The platform uses a rich data model of relevant processes. The capability to efficiently browse the contents, even for large networks, is based on the Google Maps API. Cross-linking of standardized knowledge is provided by usage of well-defined ontologies and vocabularies. The platform allows projection of high-dimensional data on curated knowledge, facilitating its interpretation. The platform is applied to the map of molecular interactions on Parkinson's disease. The contents of the map are openly accessible online (pdmap.uni.lu). Our approach grants access and easy exploration capabilities to the research community. Interpolation of different sources of information provides new insights into the curated knowledge. In the future, this methodology can facilitate cross-repository comparison of expert knowledge. As our platform hosts more 'disease maps', this goal will be supported by tangible underlying datasets.

2 - Time to Go Home: the Financial and Quality Implications of Reducing Postnatal Hospital Stay

John Bowers

Length of stay on postnatal wards in Scotland has fallen substantially; in England 58% of women have a stay of less than 24 hours. This study explored the possible implications of further reductions in postnatal stay using data from a variety of sources including: National Maternity Survey, NHS Information Services Division, National Midwifery Workforce Planning, local NHS Boards, interviews with mothers and

staff. These data enabled a number of inter-related studies using a range of statistical, economic and simulation models to examine the consequences of marginal reductions in hospital stay. The studies explored the bed and staff requirement, the effects on various measures of the inpatient quality of care, and the possible implications for community postnatal care. Cost savings may well be possible but if quality of care is to be maintained they will be significantly less than a simple analysis might suggest. Much of the hospital care is associated with the admission and discharge of the mother and baby: any further reduction in hospital stay will be largely achieved through shortening the intermediate recovery time, when the care is less intensive and it is provided by less qualified, cheaper staff.

3 - Pharmaceutical Advertising in the Presence of Generic Drug Considering Physician-Patient Interaction

Farshid Jamali, Ata G.Zare, Farin Jamali, Sara Mobarak Abadi

In the pharmaceutical market, physicians are the core of attention in drug prescription. Pharmaceutical industries use sales representatives to target physicians(detailing advertising) and also employ DTCA(direct to consumer advertisement) to target the patients. DTCA includes two main methods:constructive and combative strategy, respectively. In our model, it is assumed that there are three types of drugs in the market:brand 1 and brand 2, produced by firm 1 and firm 2, respectively, and also a generic drug. The price of the generic drug is lower than the price of the brand drugs; however, the brand drugs have higher quality and are advertised trough effective methods. It is assumed that there are two groups of patients. People in the first group are aware of the existence of prescription treatment for their ailment (exposed to the combative DTCA) and will meet the physician on their own; due to their awareness, they may suggest a specific drug. The remaining patients have potential to consult a physician if they are exposed to constructive DTCA. In the previous studies, the impacts of the advertising policies were addressed in a market that all customers have ability to purchase the drug; however, in our model one type of drugs in the market is generic. First, we determine the combative DTCA level of each firm that maximizes the firm's profit function. Then, the equilibrium behavior and the effects of market parameters on the firm's market share and profit are studied.

Monday, 12:30-14:00

■ MC-01

Monday, 12:30-14:00 - Barony Great Hall

Keynote Lecture: Markku Markkula

Stream: Plenary, Keynote and Tutorial Sessions
Keynote session
Chair: *Ahti Salo*

1 - Regional Innovation ecosystems pioneering the Europe 2020 development - integrating top-down and bottom-up

Markku Markkula

The main target of the presentation is to challenge the academic OR researchers to deepen their systems thinking on the on-going societal transformation, which is often called the paradigm shift to digitalized knowledge economy. The presentation will include theories and practices of the latest EU policy guidelines, i.e. regional smart specialisation strategies, knowledge triangle, and the need to renew the triple helix concept to quadruple helix and to innovation ecosystems.

The future EU Urban Agenda can defined in a new way: The future smart cities function as mutually complementary ecosystems, where different actor groups and actors collaborate to discover the optimal balance in 1) urban economic activities, 2) comfortable, invigorating and human-scale living environments, and 3) synergistic innovation processes for continuous renewal.

This means that future urban ecosystems can be seen in a much broader context than before: as orchestrated platforms for testing emerging concepts and technological solutions for a sustainable tomorrow. Furthermore, Europe needs to investigate how to turn the accumulating know-how into competitive and successful business models, processes and operations.

■ MC-02

Monday, 12:30-14:00 - Barony Bicentenary Hall

EURO Excellence in Practice, part I

Stream: EURO Awards and Journals
Award Competition session
Chair: *Luca Maria Gambardella*

1 - A Novel Analytic Framework for Sustainable Development of Electronic Government Services from Stakeholders' Perspectives

Ibrahim H. Osman, Abdel Latef Anouze, Zahir Irani, Baydaa Al-Ayoubi, Habin Lee, Asım Balcı, Tunç Medeni, Vishanth Weerakkody

Electronic government services (E-Services) involve the delivery of information and shared-value services to various stakeholders via the internet of things. They are characterized by high-capital investments and low-citizen take-ups. The evaluation of such e-services has been a challenging task due to several factors: technological and human aspects; lack of real-experience data; and inappropriate analytical tools to make informed decisions for their sustainable development. A novel analytical framework has been developed over several phases including: conducting focused-group interviews with stakeholders to identify variable measures on users' concern to complement the literature; developing of online surveys to collect real-interaction data; validation of relationships among variables using structured equation-modeling to develop a Cost-Risk and Benefit-Opportunity Analysis (COBRA) framework; establishing a user's satisfaction index using the relative ratio of the sum of the weighted multiple-impact (benefit and opportunity output and outcome) variables over the sum of the weighted multiple-input (risk and cost) variables. The frontier data envelopment analysis is then used to find the optimal weights to measure the relative efficiency of multiple-input utilization over the effectiveness of multiple-impact generation. The framework has been validated on

a set of Turkish's e-services. Similarly, it was further validated and generalized on sets of e-services in Qatar, Lebanon and UK from the perspectives of both users and providers.

The proposed framework has a number of managerial, policy and practical implications including: provision of analytical tools that determined the gaps in satisfaction among stakeholders for the first time in literature; identification of best-practice national benchmark for learning and development; generation of applied insights to reduce cost and increase take-ups; determination of effectiveness and efficiency indices to help policy makers in measuring the impact of policies on change over time and to prioritize e-services for resources allocation; easy to adopt by government agencies worldwide.

2 - Spare Parts Inventory Control for an Aircraft Component Repair Shop
Willem van Jaarsveld, Twan Dollevoet, Rommert Dekker

We study spare parts inventory control for an aircraft component repair shop. Inspection of a defect component reveals which spare parts are needed to repair it, and in what quantity. Spare part shortages delay repairs, while aircraft operators demand short component repair times. Current spare parts inventory optimization methods cannot guarantee the performance on component level, which is desired by the operators. To address this shortfall, our model incorporates operator requirements as time-window fill rate requirements for the repair turnaround times for each component type. In alignment with typical repair shop policies, spare parts are allocated first come first serve to repairs, and their inventory is controlled using (s,S) policies. Our solution approach applies column generation in an integer programming formulation. A novel method is developed to solve the related pricing problem. Paired with efficient rounding procedures, the approach solves real-life instances of the problem, consisting of thousands of spare parts and components, in minutes.

A case study at a repair shop reveals how data may be obtained in order to implement the approach as an automated method for decision support. We show that the implementation ensures that inventory decisions are aligned with performance targets.

3 - Let a River Run through It: Optimising River Connectivity Restoration
Jesse O'Hanley

River systems across the globe are heavily impacted by the presence of large numbers of in-stream structures, such as dams, weirs, culverts, and other river crossings. Such structures often form physical barriers that disrupt the natural connectivity of rivers, thus preventing fish and other aquatic organisms from accessing essential breeding and rearing habitats. In this talk, I will present a state-of-the-art optimisation-based methodology for prioritising river barrier repair and removal decisions. The methodology was originally developed through a collaborative project with the California Fish Passage Forum, a consortium of state and federal government agencies and nongovernmental organisations whose mandate is to improve river access for migratory fish throughout California. To help the Forum and other organisations run the optimisation model, a software tool called OptiPass was developed using open source COIN-OR callable libraries. The software, which comes replete with a graphical user interface, allows non-technical users to quickly and easily generate optimal barrier mitigation solutions. The optimisation model underpinning OptiPass represents a radical improvement over the ad-hoc methods commonly used in barrier prioritisation planning. The presentation will include an overview of the optimisation framework, which makes use of a sophisticated linearisation technique known as the "probability chain' method, as well as a small demonstration of the OptiPass software and a discussion about how the methodology has been used by the Forum to take a far more strategic approach to barrier mitigation planning.

■ MC-03
Monday, 12:30-14:00 - TIC Auditorium A, Level 2

Roundtable Session for PhD Students

Stream: Operations Research, other
Contributed session
Chair: *Bernd Wurth*

1 - Roundtable Session for PhD Students
Bernd Wurth

This roundtable session is a great opportunity for current and recently graduated PhD students to get advice and feedback from a number of academics and practitioners. In small groups, you can have a chat with academics and practitioners at different stages of their careers for hints and tips about jobs, career development, research opportunities, and so on.

■ MC-04
Monday, 12:30-14:00 - TIC Auditorium B, Level 2

Retail Inventory Management II

Stream: Demand and Supply in Retail and Consumer Goods
Invited session
Chair: *Rob Broekmeulen*

1 - Periodic Review and Continuous Ordering
Dennis Prak, Ruud Teunter, Jan Riezebos

Many inventory control studies consider either continuous review & continuous ordering, or periodic review & periodic ordering. Mixtures of the two are hardly ever studied. However, the model with periodic review and continuous ordering is highly relevant in practice, as information on the actual inventory level is not always up to date while making ordering decisions. This paper will therefore treat this model. Assuming zero fixed ordering costs, and allowing for a non-negative lead time and a general demand process, we first consider a one-period decision problem without salvage cost for inventory remaining at the end of the period. In this setting we derive a base-line optimal order path, described by a simple newsvendor solution with safety stocks increasing towards the end of a review period. We then show that for the general, multi-period problem, the optimal policy in a period is to first arrive at this path by not ordering until the excess buffer stock from the previous review period is depleted, then follow the path by continuous ordering, and stop ordering towards the end to limit excess stocks for the next review period. An important managerial insight is that, typically, no order should be placed at a review moment, although this may seem intuitive and is also the standard assumption in periodic review models. We illustrate that adhering to the optimal ordering path instead can lead to cost reductions of 30% to 60% compared to pure periodic ordering.

2 - Managing Inventory Using a Classification: Setting the Right Service for the Right Class
Erwin van Wingerden

In this paper we consider the multi-item, single-echelon inventory optimization problem where the company wants to achieve the target service level, measured as the aggregate fill-rate, while having minimum inventory holding costs. For this problem we often see companies applying a classification because the implementation of SKU-specific inventory control methods is too complex. However, even though controlling SKUs using a classification is straightforward, there are no clear guidelines on what information should be used to classify the SKUs, where to put the boundaries for the different classes, and on how to set the targets for each of the classes. We use data of a maintenance company and compare the results when using a classification with the results of using an item approach and system approach. We look at which information should be used to classify the SKUs, and whether a two-dimensional classification is better than a one dimensional classification. Moreover, we look at how to set the boundaries, which determine how the SKUs are distributed over the different classes. We show that the information used and where to put the boundaries can have a great impact on the performance, and that the optimal boundaries can depend on the target service level. Finally, we propose an algorithm to set the targets for the different classes based upon a greedy approach such that we don't have to enumerate all possibilities.

3 - On the Calculation of Safety Stocks: Dealing with Forecast Errors
Ruud Teunter, Aris A. Syntetos, Dennis Prak

In forecasting and inventory control textbooks and software applications, the variance of the demand per period is assumed to be either known or estimated by the one period ahead forecast error. The lead time demand variance, essential for safety stock calculations, is then obtained by assuming independence of demand (forecast errors) for different periods of the lead-time. However, as argued in this paper,

the demand forecast errors are in fact positively correlated and often highly so. For systems where demand fluctuates around a constant level and with a constant lead-time, we present corrected lead time demand variance expressions. Moreover, we show (for normally distributed demand) that traditional approaches can lead to safety stocks that are up to 30% too low and service levels that are up to 10% below the target for realistic settings. The 'problem' of correlated forecast errors exists for all forecasting techniques and all demand processes, and therefore is a fundamental issue for inventory control that deserves wider recognition, offers ample opportunities for further research, and should lead to modification of existing software.

4 - Replenishment Policy for Items Having a Fixed Shelf Life under Permissible Delay and Variable Lead Time

Sarbjit Singh, Amarjeet Singh

All organizations whether manufacturing or service have to keep inventory for smooth running of their business processes. This study is devoted to the items like medicines, cosmetics which are having fixed shelf life i.e. they will be of no use after some prescribed time. This model also considers the permissible delay which means that the buyer can pay for goods after some fixed time and has to pay interest after that fixed time. The demand considered here is stock dependent demand. The lead time varies as per the availability of the product and follows normal distribution. The optimality of the model has been checked and numerical illustrations with sensitivity analysis are given to prove the validity of the model. The model has also been applied on one cosmetics store (Lucky's Beauty Zone) and found to be relevant in deciding the optimal cycle time.

■ MC-05

Monday, 12:30-14:00 - TIC Auditorium C, Level 2

Sustainable Bio-Energy

Stream: OR for Energy and Resource Efficiency
Invited session
Chair: *Lars-Peter Lauven*
Chair: *Luis C. Dias*

1 - Integrating Life-Cycle Assessment and Multi-Criteria Decision Analysis to compare biodiesel alternative chains

Luis C. Dias, Carolina Passeira, João Malça, Fausto Freire

In this work we compare four Rapeseed Methyl Ester biodiesel production chains, corresponding to four different feedstock origins. The environmental impact of each chain is assessed in the context of a Life-Cycle Assessment (LCA) encompassing cultivation, transportation to Portugal, extraction and transesterification. We apply two different Multi-Criteria Decision Analysis (MCDA) additive aggregation methodologies to aggregate various impact categories resulting from the Life Cycle Impact Assessment (LCIA) phase of the LCA. The chosen MCDA methodologies, Stochastic Multi-Attribute Analysis and Variable Interdependent Parameter Analysis, are two complementary approaches to address one of the main difficulties of MCDA: setting the relative weights of the evaluation criteria. Indeed, weighting the various impacts in the LCIA phase is a controversial issue in LCA research and studies. The LCIA-MCDA approach proposed in this work does not require choosing a specific weighting vector, seeking to assess which conclusions are robust given some freedom allowed in the choice of weights. To study further the robustness of the conclusions, the effects of removing one criterion are analysed, one at a time.

2 - Greenhouse gas assessment of German biogas production in context of regional production circumstances and economically optimized feedstock choice

Sebastian Auburger, Anna Jacobs, Bernward Märländer, Enno Bahrs

In Germany, subsidizing renewable energies is justified by lower greenhouse gas (GHG) emissions in comparison to fossil energy sources. Especially for power production based on biogas, subsidies were comparably high which led to an extension of biogas plants (BGP), generally fed with energy crops or manure from livestock. In order to assess GHG emissions from biogas production in Germany,

our model consists of two parts and considers around 8,000 geocoded BGP. (i) Production costs of energy crops (silage corn, sugar beet, winter wheat whole crop silage, winter wheat grain) were calculated for each BGP taking regional production circumstances into account. Specific methane yields of energy crops and of manure were derived from own experimental data and from literature values. Feedstock mix characterized by minimized costs was solved as a linear problem, subject to restrictions established by bonus system of the German Renewable Energy Act and to energy demand of the BGP. (ii) In terms of GHG emissions from biogas production, energy crop production and BGP operation were considered. Therefore, plant specific GHG emissions were calculated as kgCO2eq and related to 1 kWh produced. The model showed that silage corn was the optimal feedstock in most cases, followed by manure like in practice. In terms of GHG emissions, 0,14 kgCO2eq/kWh (nationwide mean of all BGP) were emitted from BGP in Germany, with variations depending on regional production circumstances.

3 - Optimizing a Multiproduct Biorefinery under Consideration of Spatial Data using Evolutionary Strategies and Nonlinear Programming

Tim Schröder, Lars-Peter Lauven, Jutta Geldermann

The substitution of fossil resources by using renewables is one of the major challenges of the present. Biorefineries can use renewable resources instead of fossil resources and still provide a similar product portfolio. This paper presents an optimization approach for a multiproduct Fischer-Tropsch biorefinery in a continuous solution space, simultaneously taking location, capacity and setup planning into account.

The spatial data used leads to a "rough' objective function, which is difficult to solve using exact optimization algorithms. However, evolutionary algorithms and evolutionary strategies in particular, offer suitable heuristics for finding good solutions in such cases. Considering the exact setup of such biorefineries implies many strict constraints and interdependencies between different upgrading units. Under these circumstances, evolutionary strategies may deteriorate to a random search or find non-optimal corner solutions. To tackle this problem, a nonlinear program is nested in the evolutionary strategy in order to determine the optimal setup for a given location and capacity in a continuous solution space.

It is shown that the evolutionary strategy quickly and reliably converges towards the — supposedly — optimal solution.

■ MC-06

Monday, 12:30-14:00 - TIC Lecture Theatre, Level 1

POM Applications I

Stream: Production and Operations Management
Invited session
Chair: *Zdzislaw Hejducki*

1 - Integrated planning of shifts and worker training for new product introduction in the automotive industry

Sina Wochner, Martin Grunow

Shortened product life cycles and increased product ranges in the automotive industry have led to more frequent production ramp-ups of new car models. Performing these production ramp-ups as cost efficient as possible has become a major concern for OEMs. We focus on the changeover from an old to a new car model on a dedicated production line. Due to the low volumes during the changeover and ramp-up phase, the workers are often only partially used for production operations. However, to qualify the workers for the assembly of the new car model, training sessions are necessary. In order to efficiently use the available working time, the planning of the production ramp-up and the training sessions should be carried out in an integrated fashion. Thus far, no approaches exist that address this special situation. We fill this research gap by exactly defining the planning problem and presenting a mixed-integer linear programming model, which integrates shift with production and training session planning. Numerical results based on test instances adapted from a large German OEM show the applicability of our approach.

2 - Minimum capital cost design of a chemical blending plant with dedicated parallel blending lines
Floor Verbiest, Trijntje Cornelissens, Johan Springael

Production plants worldwide face huge challenges in satisfying high service levels and in outperforming competition. These challenges require the right strategic decisions on plant design and production strategies. The design problem of multiproduct batch plants, where all products follow the same processing path, has been generally formulated as mixed integer nonlinear programming models minimising capital investment. Most of these design models, which assume single product campaign mode operation and allow for parallel machines, consider that different products are produced one at a time.

In our research, we optimise the design of a chemical blending plant for which all products pass through the blending stage, and next, after intermediate storage, the filling stage. These plants are typically equipped with parallel blending lines so that different products may be produced at the same time, which is considered as an aspect of multi-purpose plants. Through the incorporation of several aspects of multi-purpose models into the current multiproduct models, we can exploit these parallel lines. We introduce dedication of blending lines to specific product families so as to avoid changeover time and cost. We will present a mathematical formulation to determine the optimal number and size of each equipment type in order to represent a chemical blending plant with product dedication, and the results obtained for different product demand.

3 - System supporting scheduling of transportation composite beam bridge structures
Zdzislaw Hejducki, Wojciech Bożejko, Mieczysław Wodecki, Ewa Hejducka

This paper presents a mathematical model, the theoretical basis and an outline of a computer module system supporting scheduling of transportation and assembly of composite beam bridge structures implemented in the just in time system (called JIT for short). In the optimization procedures there were used algorithms based on the tabu search method.

Organization of work in the JIT system allows us to synchronize the supply (prefabrication transport) with the installation, thus avoiding the need of storage. It requires, at the same time, solving of many difficult (strongly NP-hard) optimization problems .There are currently no known optimal algorithms for solving the problems of the polynomial-time computational complexity. Therefore, there are usually fast approximate algorithms (of polynomial-time computational complexity, with no guarantee of optimality). The paper concerns new issues of application of prefabrication bridge components for reconstruction of the transportation network (rail and road one) to ensure collision-free roads. In recent years, there have been developed new technological solutions, using polymer composites (Fibre Reinforced Polymers called for short FRP).They consist of the composites of plastics reinforced with various fibers. Most of them are carbon, glass or aramid fibers. Due to a number of the beneficial properties, such materials find more and more practical applications, including bridge construction.

■ MC-08

Monday, 12:30-14:00 - TIC Conference Room 2, Level 3

Large Optimization Problems

Stream: OR and Real Implementation
Invited session
Chair: *Belarmino Adenso-Diaz*

1 - A metaheuristic algorithm for the eco-efficient urban waste collection routing problem
Ignacio Eguia, Jose Carlos Molina, Jesus Racero, Fernando Guerrero

This paper focuses on redesigning the urban waste collection routes with a single dump site using eco-efficiency as a performance indicator. In this problem there are a limited number of heterogeneous vehicles based at a single depot. Empty vehicles leave the depot, collect waste from a set of locations and emptying the collected waste at the single available dump site. Vehicles leave the dump site and collect more waste from other locations or return to the depot empty. Traditional

performance indicators in Vehicle Routing Problems are mainly focused on economic objectives, not considering explicitly environmental issues. In this paper, a mathematical model with an eco-efficient objective function that takes into account internal costs (driver, fuel, maintenance) and external costs (climate change, air pollution, noise and accidents) is presented. The problem is first solved heuristically using an insertion-based construction algorithm. Solutions are then improved in a tabu search algorithm developed for this problem. The tabu search algorithm is validated for a real problem in the municipality of Alcalá de Guadaira, within the metropolitan area of Seville (Spain). Real distances between locations are calculated with Open-StreetMap. The application of the proposed algorithm using different objectives functions gives routes that considerably improve those that are currently used in the municipality.

2 - A GDF Suez novel approach to the efficient solution of the thermal unit commitment problem with coupling constraints
Dimitri Tomanos

GDF Suez would like to optimize the commitment of a large number of thermal power plants on a medium term horizon, while taking into account supply delivery, storage and ancillary services constraints. Getting to find a solution combining a long modelling horizon, with a fine time granularity, and using a detailed representation of the plants and constraints, is difficult to achieve in a reasonable amount of time (less than one hour).

We propose a novel approach to find an accurate solution in a reasonable amount of time, without performing any model approximation, implementing a "smart' time decomposition.

Optimisation decisions are generally driven by only a few exogenous model parameters: maintenance, market prices... As a result, time periods exhibiting similar exogenous parameter values often conduct to the same decision in terms of commitment and dispatch. The idea is to find a smart way to group all the hours during which parameters present the same characteristics.

Following this new smart time bucketing definition, the number of time buckets can generally be reduced by a factor of 10 with respect to the hourly decomposition, speeding up the optimisation process significantly. For instance, a thermal unit commitment problem on 15 plants, with coupling constraints, on a one-year horizon, can typically be solved in less than 10 minutes. Last but not least, the solving time shows remarkable stability on the different problems solved with our new approach.

3 - A framework for large-scale single- and multiobjective engineering optimisation problems with computationally expensive responses
Yury Korolev, Vassili Toropov

Problems of optimisation of modern engineering systems are often characterised by a large number of parameters (in turbomachinery applications, for example, one may have to deal with thousands of design variables). On the other hand, state-of-the-art numerical models - such as those in Computational Fluid Dynamics - require hours, and sometimes days, for one design evaluation. Consequently, engineering optimisation problems are affected by both the curse of dimensionality and a long run time of response evaluation. Furthermore, one has to take into account noise and occasional failures of response evaluation.

Therefore, optimisation methods that are economical in terms of function evaluations and robust against the numerical noise and response evaluation failures are highly desirable. The situation gets even more complicated in multi-objective optimisation problems, where one needs to solve a number of single-objective problems to get an approximation of the Pareto front.

The Multipoint Approximation Method is a framework for single- and multiobjective engineering optimisation problems which attempts to overcome the abovementioned challenges. It combines metamodelling techniques with a trust-region strategy and is capable of using parallel computing systems in an efficient manner. In this paper we will present a general scheme of the Multipoint Approximation Method and focus on the recent developments undertaken to make it suitable for multiobjectve problems.

4 - Minimizing deviation from scheduled times in a Single Mixed-operation Runway
Belarmino Adenso-Diaz, Alexia Rodriguez Diaz, Pilar González-Torre

The dynamic nature of the airport terminal area requires the development of scheduling computationally efficient algorithms and therefore amenable to replanning when new events occur. The challenge lies in simultaneously achieving safety (separation between aircrafts), efficiency (low average delay), and equity (limiting the deviation from a nominal order or by minimizing variance in delay). The main objective of this research is to develop an algorithm that minimizes deviations from scheduled time of arrival and departure flights in an airport under minimum wake vortex, slots, and Constrained Position Shifting (CPS) constraints. A slot is the scheduled time of departure or arrival available or allocated to an aircraft movement at a specific date, but not necessarily the real time for aircraft operation due to bad weather, airspace congestion, or ground-handling problems, among other factors. On the other hand, CPS methodology is based on the specification of the maximum number of position shifts that any aircraft will receive with respect to its first-come first-serve (FCFS) position. We will consider a scenario with a single mixed-operation runway. The objective is to calculate the Target Times than minimize the deviation from the scheduled time in real time. A quick metaheuristic approach was taken based on Simulated Annealing. The results obtained by the proposed algorithm would be compared with the FCFS option using real airport data.

■ MC-09

Monday, 12:30-14:00 - TIC Conference Room 3, Level 3

MAI: System Dynamics: do and don't

Stream: Making An Impact 2 (MAI 2)
Invited session
Chair: *Martin Kunc*

1 - System Dynamics: do and don't
Martin Kunc

This workshop proposes a tour through System Dynamics, a widespread modelling and simulation tool, through applications and insights into its use in organisations and in research. The workshop is ideal for System Dynamics novices, and those with relatively limited experience, looking to share and build knowledge and effectiveness.

■ MC-12

Monday, 12:30-14:00 - TIC Conference Room 4&5, Level 3

OR and Climate Change 2

Stream: OR and Climate Change
Invited session
Chair: *Monica Castaneda*

1 - Reduction of the carbon footprint in the external supply of raw materials in the automotive industry
Juan Bermeo, Victoria Rodriguez, María Jesús Alvarez

Currently the environmental impact has been reflected negatively as a result of bad business practices. This has led to increased global warming. For this reason, green logistics is an issue that has generated the interest of companies and governments in the supply chain management. The supply plays an important role and it is a key factor in the green logistics. The aim of this study is to evaluate the environmental impact of the different supply decisions such as the number of stops that a truck can make and the maximum travelled distances of the milk run routes. In addition the expected averaged inventory level will be analyzed. In this research an algorithm is developed. This algorithm evaluates the supply decisions with the aim of minimizing the environmental impact by reducing carbon emissions. For the development of this work an important company in the automotive sector was selected under a JIT strategy.

2 - Renewable Energy Revolution: new business models for electric utilities
Monica Castaneda, Isaac Dyner Rezonzew, Carlos Jaime Franco

The technology shift from fossil-fuelled systems to renewable energies has been promoted by governments with the purpose of decarbonising the electricity industry. Nevertheless, rapid technology progress has prompted a disruptive change that is transforming market structures. Electricity utilities with traditional business models, particularly those based on fossil-fuel plants, are shifting from their static and reliable position to confront disruptive renewable challenges. Under these circumstances, it is necessary to reinvent their business models to survive. In this new industry environment, threats and opportunities must be clearly understood.

The purpose of this paper is to identify major threats and opportunities for electricity utilities, with the support of a simulation model. The unit of analysis is the firm and its rivals, focusing on their corresponding resources and capabilities. Through simulation runs, this paper concludes that the major threat for utilities is micro-generation; but at the same time, new opportunities emerge as micro-generation creates new market niches.

■ MC-15

Monday, 12:30-14:00 - TIC Conference Room 6&7, Level 3

Cutting and Packing 3

Stream: Cutting and Packing
Invited session
Chair: *Takashi Imamichi*
Chair: *Takashi Imamichi*

1 - Jostle Heuristic for 2D-Irregular Shaped Packing Problems with Free Rotation
Ranga P. Abeysooriya, Julia Bennell, Antonio Martinez Sykora

This paper investigates the 2D-irregular packing with a single and multiple stock sheets. We adopt the Jostle algorithm, where shape placement oscillates between the ends of the stock sheet, and suggest some improvements. We present alternative strategies for handling the degree of rotation, use of hole-filling and placement policy with the jostle approach. All variants are compared using quality of packing and execution time. Findings reveal that irrespective to hole-filling, Jostle performs better when free rotation of shapes is permitted.

2 - An Iterative Approach for Nesting Problems Based on GPU Computing
Pedro Rocha, A. Miguel Gomes, Rui Rodrigues, Cláudio Alves

In this paper, we propose an iterative search algorithm for the irregular strip packing problem (or nesting problem). In this problem irregular shapes have to be placed on strips representing a piece of material whose width is constant and unlimited length. Our approach relies on the use of graphical processing units to accelerate the computation of different geometrical operations. The approach is based on a greedy placement rule, which iteratively places a piece one by one. Preliminary computational experiments with benchmark datasets showed promising results.

3 - Monotone Polygonal Chain Representation for Irregular Packing
Takashi Imamichi

Cutting and packing problems with irregular shapes have a lot of applications such as textile and steel industry and have been extensively studied. Measuring the amount of overlap of shapes plays an important role to design efficient algorithms. However, it is not easy to calculate the exact penetration depth or overlapping areas in general. Some approximation schemes of shapes are proposed to deal with the difficulties, for example, bitmap approximation and scan line approximation. We propose a new approximation scheme called the monotone polygonal chain representation. We consider two non-overlapping monotone polygonal chains and their internal as a building block, called monotone polygonal chain enclosure, and represent given shapes by a set of the enclosures. We show that the computation of penetration depth of the enclosures is simple thanks to the simplicity of monotone polygonal chains. We design an algorithm to find a layout of shapes by minimizing the penetration depth of the enclosures and report the results of computational experiments.

■ MC-16

Monday, 12:30-14:00 - TIC Conference Room 8, Level 3

Design and Management of Sustainable Supply Chains

Stream: Sustainable Supply Chains
Invited session
Chair: *Grit Walther*

1 - Coordination of Sustainability Efforts in global Supply Chains
Rob Zuidwijk

There is growing pressure on particular organizations that operate in global supply chains to enhance their environmental and societal performance, next to economic. These organizations seek to take action to do so, but they usually need other organizations in their global supply chains to exert effort as well. In particular, it is not uncommon that downstream brand organizations (final product producers, retail organizations) feel the immediate pressure, while more upstream organizations (agriculture, raw material production) are causing most of the environmental and societal externalities. This calls for coordinative measures. The presentations will elaborate on coordination mechanisms in supply chains to achieve optimal efforts in supply chains, in particular for the case of carbon emission reduction. The presentation will elaborate on existing work while new research directions are explored as well.

2 - Sustainable Supply Chain Strategic and Tactical Decisions
Ana Barbosa-Povoa, Bruna Mota, Maria Isabel Gomes, Ana Carvalho

A mixed integer linear programming model is developed for the design and planning of closed-loop supply chains. A 4-echelon structure is modelled including suppliers, factories, warehouses and markets. Different decisions are accounted for: supplier selection and purchase levels; facility location and capacity; technology selection and allocation; product recovery and remanufacturing strategies; transportation network definition with intermodal transportation options; inventory policies and stock amounts; and supply planning. Three objectives are modelled. The economic objective is measured through Net Present Value. The environmental objective is measured through Life Cycle Assessment methodology ReCiPe. The social objective is measured through a developed indicator that relates the number of jobs created by the supply chain with the maximization of job creation in countries with lower economic development. This is measured through Gross Domestic Product, as used by the European Commission in funding allocation decisions. The model is applied to a case-study of an electronic components producer that is planning an expansion in Europe and in Brazil. The -constraint method is applied so as to determine compromise solutions between the three objectives. Results show significantly different solutions when considering the three objectives separately. Important managerial and political insights can be taken from the analysis of compromise solutions obtained through this work.

3 - Design and Planning of Green Globalized Supply Chains: the Merit of "Slow Steaming'
Ioannis Mallidis, Eleftherios Iakovou, Rommert Dekker, Dimitrios Vlachos

Under the context of the EU and IMO's proposed legislative interventions for reducing shipping greenhouse gas emissions, the concept of "slow steaming' has emerged as an effective practice towards this direction, while additionally providing significant profitability to the ship owners' through the reduction of their ships' voyage fuel costs. On the land part of a supply chain supply however, lower ship speeds increase the lead time required for the replenishment of a cargo owner's order. This may in turn lead to: (i) higher inventory holding costs for the cargo owner; (ii) higher pipeline inventory holding costs; (iii) higher distribution centers' operating costs and CO2 emissions as more and larger facilities would be required. To this respect, cargo owners are concerned that they will end up carrying these costs while only the ship owners will enjoy the resulting green image improvements and cost reductions by implementing slow steaming. Under this context, the purpose of this paper is to quantify the impact of slow steaming on the cargo owner's facility location and inventory planning decisions, under cost and CO2 emissions optimization criterions, and thus to explore the value of potential freight rate changes for compensating against these impacts.

4 - Mapping and Evaluation of Approaches for Supply Chain Environmental Sustainability Performance
Andrea Tuni, Athanasios Rentizelas

Climate change, scarce natural resources, environmental regulations and demand for green products are some of the reasons that drive companies to consider environmental issues within management. Thus, a number of metrics has been developed to measure environmental performance. However, considering that competition has shifted from a company-versus-company form to a supply chain-versus-supply chain one, this topic cannot be addressed at a single company level anymore; a broad and holistic approach is needed, encompassing the whole supply chain.

Although several studies have addressed the integration of environmental issues in supply chain management, a huge variety of metrics adopted to assess environmental performance in this field still exists. The aim of this work is to map and evaluate the existing approaches adopted to assess environmental sustainability performance along the whole supply chain, to discuss their strengths and limitations, as well as to introduce a multi-dimensional classification of the approaches. The classification will focus on the qualitative or quantitative nature of each approach, whether the design or the operational stage of the supply chain is addressed and whether other dimensions of sustainability are considered

This work can serve as a starting point for future studies that aim to integrate different approaches and proceed towards a standardisation in the assessment of environmental sustainability performance at a supply chain level

■ MC-17

Monday, 12:30-14:00 - TIC Conference Room A, Level 9

Applications in Game Theory

Stream: Game Theory, Solutions and Structures
Invited session
Chair: *Josep Freixas*

1 - Dimension of the European Union Council according to the Lisbon Treaty
Sascha Kurz, Stefan Napel

In this talk we prove that the voting system of the European Union Council according to the Lisbon Treaty can not be represented as the intersection of six or fewer weighted games, i.e., its dimension is at least seven, which makes it the current record holder within the class of real-world voting systems. Using (heuristic) discrete optimization techniques we compute a representation as the intersection of a few thousand weighted games. The exact determination of the dimension of the present EU voting system is introduced as a challenging computational problem. The Boolean dimension is determined to be exactly three.

2 - On the Complexity of some Specific Problems on Simple Games
Xavier Molinero, Martin Olsen, Maria Serna

This work is a follow up of results given in [1]. Here we present some computational complexity results for specific problems and simple games. For instance, we consider the complexity of determining trade robustness for a given simple game in the four natural explicit representations: winning, losing, minimal winning, and maximal losing. Our results show that the problem is solvable in polynomial in some cases but in other it is NP-hard depending on the input and the output. We also define the j-trade application for a given simple game and we analyze how to find such j-trade application in those natural forms of representation. We conclude stating some conjectures and open problems. For instance, given a simple game, we consider how to compute the dimension and the co-dimension [2,3], and how to represent such game by a union or an intersection of some weighted games.

[1] J. Freixas, X. Molinero, M. Olsen and M. Serna (2011). On the complexity of problems on simple games. RAIRO - Operations Research, 45, pp. 295-314. [2] V.G. Deineko and G.J. Woeginger (2006). On the dimension of simple monotonic games. European Journal Of Operational Research, 170, pp. 315 - 318. [3] J. Freixas and D. Marciniak (2009). A minimum dimensional class of simple games.

TOP: An Official Journal of the Spanish Society of Statistics and Operations Research, 17, pp.407-414.

3 - Positional Power in the Institutional Setting of the European Union
Frank Steffen

The Treaty of Lisbon elevated the co-decision procedure of the Maastricht Treaty to the main law-making procedure of the European Union. The reform sought to redress the balance of power in the decision making system, thus addressing an important element of that democratic deficit critique, which laments the weakness of the European Parliament relative to the Council of the EU and the European Commission. The ordinary legislative procedure, as the procedure is now called, is claimed to equalize the powers of the Parliament and the Council. In this paper we test whether this claim is justified using a formal power analysis. We apply the positional power measure of van den Brink and Steffen, which is especially designed to measure power in a sequential decision-making processes such as that involving the three institutions of the EU. Contrary to previous studies of inter-institutional power distribution in the EU, the positional power measure is an a priori measure which does neither factor possible distributions of actors' preferences, nor tries to account for the nature of issues on the ballot. Power arises purely from the rules of the procedure stipulated by the Treaty. We found that while the reform has indeed strengthen the Parliament, it failed to equalize the powers of the Parliament and the Council. We conclude that while the Parliament gained power in the transition to the Lisbon Treaty from the Treaty of Nice, it is not nearly as powerful as the Council.

4 - Tactical Vote in Committees with Applications to Decision-Making
Josep Freixas

In (j,k)-games each player chooses amongst j ordered options and there are k possible outcomes.

We consider the case where players are assumed to prefer some outcomes to others, and note that when k is greater than two the players have an incentive to vote strategically. In doing so, we combine the theory of cooperative game theory and social choice theory.

We define the concept of a (j,k)-game with preferences, either unrestricted or single-peaked preferences, and what it means for it to be manipulable for a player. We also consider Nash equilibriums with pure strategies for these games and find conditions that guarantee their existence. Applications to several real-world problems are highlighted.

■ MC-18
Monday, 12:30-14:00 - TIC Conference Room B, Level 9

Software for Optimization Modeling 3

Stream: Software for Optimization
Invited session
Chair: *Robert Fourer*

1 - Rapid Development of Customized Optimization-Based Apps
Johannes Bisschop

Optimization models and their solutions play a crucial role in practical prescriptive decision making. However, as the demand for customized optimization-based apps is increasing in practice, there is a need to reduce the overall development & maintenance cost and speed up the process from concept to a workable app. At ThinkCubic we have worked for many years on a new and innovative technology to do just that. The presentation will provide an overview of functionality to support rapid development of customized optimization-based apps, and will also demonstrate some of the features through live demos.

2 - Changing the way business users make decisions
Alex Fleischer, Sofiane Oussedik

This presentation will give you an insight into some clients use cases in which decision aid to support the user making the decision was key. The use cases developments have been driven by the need to accomplish key business objectives and deploy the right flexible solution to the user. The presentation will include details on the the challenges faced, as well as the need for a seamless integration with existing systems and processes.

3 - Selection and allocation of fire-fighting resources for wildfire containment
Jorge Rodriguez Veiga, Balbina Casas-Méndez, María José Ginzo Villamayor

Determining the specific mix of fire-fighting resources for a given fire is a necessary condition for identifying the optimum management cost. In the last decades, related studies have been done.

In this talk, we present a mixed integer linear programming model developed taking into consideration the requirements given by INAER, a Spanish company, leader in air emergency services. This model is close to the work of Donovan and Rideout (2003), but we extend it by determining when the selected fire-fighting resources have to start working and when they must finish. We also include some additional constraints such as breaks control or total working time.

In addition, we implemented a function in R open source software to validate the model and we propose some examples to better understand the scope. This function solves the model accurately using Gurobi solver.

A future line of development will contemplate stochastic approach for the deterministic model. In this regard, we take as a starting point the thesis of Lee (2006) that, inspired by the work of Donovan and Rideout, increases their extent by considering the fire growth as a stochastic parameter.

It is worth mentioning that this work is part of a larger project that aims to create a decision support system, efficient and safe, for coordination of air traffic in real time, which sustains the management of air assets in terms of their distribution within the fire scenario and its operating instructions.

4 - An examination of consumer preferences in postal services in Slovakia using discrete choice modeling
Urban Kovac, Ivan Dolezal

European Commission's Postal Directive recommends EU member states to better understand to the user needs and preferences for postal service. Various EU member states have employed various techniques to measure consumer preferences in postal markets that link senders and recipients. This is a challenging task that needs careful consideration of technical, economic and social environment evolution of postal consumer needs. The aim of this paper is to use discrete choice modeling methodology for measuring consumer preferences for postal services in Slovakia. The analysis examines how these consumer preferences vary across 260 residential consumers and 90 business customers, specifically focusing on differences between vulnerable (70) and non-vulnerable (190) consumers. The valuations of letter and parcel services are measured relative to the price of a stamp, and the total WTP for these services indicates that consumers value the speed of delivery and are willing to pay the higher price of a stamp when deliveries are made earlier about one day. Morning time of delivery was not important for residential and business consumers, while they value later deliveries higher in general. Businesses and residential consumers valued higher to have postal services delivery to their work or home place. We observe that both business and residential consumers were satisfied with the current state of the postal offices network coverage.

■ MC-24
Monday, 12:30-14:00 - John Anderson JA3.25 Lecture Theatre

MADM Application III

Stream: MADM Applications
Invited session
Chair: *Chia-Huei Ho*

1 - Constructing fuzzy regression models considering randomness and fuzziness
Liang-Hsuan Chen, Yi-Ju Lai

Regression analysis is one of the most important decision making tools, allowing decision makers to analyze the relationship between input variables and output variables. However, in a real world with complicated information, data are often accompanied with randomness and fuzziness. Yet, there have been few studies of regression models that have discussed these two types of uncertainty at the same time. In this study, fuzzy random variables (FRVs) are used to characterize randomness and fuzziness inherent in observations from an uncertain environment. Using FRVs, the best fuzzy regression model considering twofold uncertainty is determined based on weighted fuzzy arithmetic and the least-squares method. The best fuzzy regression model determined by the proposed approach includes a fuzzy adjustment term in this study to enhance the generalization of data types and to reduce the total estimation error of the model. An example is used to demonstrate the proposed approach.

2 - On coordinating replenishment decisions in a two-stage supply chain by considering truckload limitation based on delay in payments
Hung-Chi Chang

It is well-known that order quantity and reorder point are the main decisions in the area of inventory control in supply chain management. Recognizing the fact that coordination is a key concept in a supply chain, many researches have proposed incentive schemes, such as quantity discount, revenue sharing, and delay in payments, to achieve buyer-supplier coordination. In this research we revisit a previous study that addresses the problem of coordinating replenishment decisions in a single-upstream (supplier) and single-downstream (buyer) supply chain. The model considers that the supplier by proposing an incentive scheme based on delay in payments convinces the buyer to globally optimize the order quantity and reorder point, while due to a truckload limitation the lot size to be determined is an integer multiple of full truckload. In order to increase the applicability of above study, we first present an improved solution procedure to determine the optimal solution for the model, where the lead-time demand is normally distributed. We correct/analyze the existing numerical results and show the efficiency of improved approach. Then, we extend the model to a situation where the distributional form of lead-time demand is unknown, and apply the minmax distribution free procedure to solve the problem. Some managerial insights from the perspective of decentralized and centralized decision-making are explored analytically and numerically.

3 - Online Herd Behavior in virtual communities
Yi-Fen Chen, Meny-Wei Shen, Wei-Hung Lai

Previous studies on eWOM (i.e., opinion-based social information) have stressed the importance of peer consumer reviews in making decision. When people follow the others decision on the Internet, online herd behavior occurs. This work presents three studies examining herd behavior in virtual communities. A 2(Volume: sales/recommendation) x 2(Number of volume: relative/absolute) x 2(Number of scale: large/small) online experiment was conducted in the first study. The second study investigated herding effects using a 2(Number of experience-sharing messages: large/small) x 2(Number of recommendations: large/small) online experiment. The results and implications of this research are discussed.

4 - Group decision-making model by combining interval linguistic variables with TOPSIS
Chen-Tung Chen, Wei-Zhan Hung, Hui-Ling Cheng

Decision making is the process to find the best alternative from the all feasible alternatives. In general, multiple decision-makers and influenced factors should be considered in a decision making process. In fact, group multi-criteria decision making (GMCDM) is a rational procedure can efficiently and effectively use in handling decision making problem to improve the quality of decision process in real situation. However, the subjective opinions, preference and judgment of decision-makers are usually vague and uncertainty, it is difficult to express their evaluations by exact crisp values in the decision making process. A more reasonable way for decision maker is to use linguistic assessments instead of numerical values. In this paper, interval linguistic variables are used for experts to express their subjective opinions. Combining interval linguistic variables with TOPSIS, an interval linguistic TOPSIS is presented to determine the ranking order of all alternatives based on the opinion of each decision-maker. According to the ranking order of alternatives of each decision-maker, the alternative

order aggregation (AOA) method is proposed in this paper by applying the minimum deviation concept to aggregate the alternative rank of each decision-maker and to decide the final order of each alternative.

5 - Non-cooperative and cooperative vendor-buyer inventory models with defective items and backlogging
Chia-Huei Ho

Most research on two-level supply chain inventory policies focused on the integrated model perspective. However, in reality, not all manufacturers and retailers are entirely integrated. Therefore, it is necessary to study the two-level supply chain inventory policy under both cooperative and non-cooperative environment. Furthermore, in traditional inventory models, the optimality is been discussed under the perfect quality assumption. However, as a result of bad quality materials, careless of workers, poor performance of machines, and/or imperfect production process, an arrival lot often contains some defective items. Hence, we present stylized models to determine the optimal strategies for cooperative and non-cooperative manufacturer-retailer inventory systems under the condition that shortages allowed and defective items are in the receiving lot. By analyzing the total cost function, we will determine the optimal production/ordering policies for supply chain partners. For each model, we will develop effective iterative procedures for finding the optimal solution. Furthermore, numerical examples will be provided to illustrate the results and sensitivity analysis will be applied to see the effects of parameters.

■ MC-25
Monday, 12:30-14:00 - John Anderson JA3.14 Lecture Theatre

Multiobjective Approaches for Problems with Variable and Fixed Ordering Structure

Stream: Continuous Multiobjective Optimization and Robustness
Invited session
Chair: *Christian Günther*

1 - An Iterative Method for Solving Vector Optimization Problems
Sorin-Mihai Grad

We present an iterative method based on recent advances in scalar convex optimization that is employed for solving a class of convex vector optimization problems without scalarizing them first, by making use of some adaptive scalarization techniques.

2 - A Unified Approach to Uncertain Optimization
Christiane Tammer, Kathrin Klamroth, Elisabeth Köbis, Anita Schöbel

Most optimization problems involve uncertain data due to measurement errors, unknown future developments and modeling approximations. For companies, these uncertainties could be future demands that have to be predicted in order to adapt the production process. In risk theory, assets are naturally affected by uncertainty due to market changes, changing preferences of customers and unforeseeable events. Consequently, it is highly important to introduce uncertain parameters to optimization problems.

Different approaches regarding uncertain optimization problems have been concentrated on in the literature. First, stochastic optimization assumes that the uncertain parameter is probabilistic. The second approach is called robust optimization, which expects the uncertain parameter to belong to a set that is known prior to solving the optimization problem. The focus lies on looking at the worst case, hence no probability distribution is needed. Other approaches to deal with uncertainty concern online optimization and a posteriori approaches uncluding parametric optimization.

In this talk we consider scalar uncertain optimization problems. We show that it is possible to apply methods from vector optimization in general spaces, set-valued optimization and scalarization techniques for developing a unified characterization of different concepts of robustness and stochastic optimization also for the case of infinite uncertainty sets.

3 - Set Optimization with Variable Ordering Structures
Gabriele Eichfelder, Maria Pilecka

In multiobjective optimization with variable ordering structures the partial ordering structure in the image space is replaced by a variable ordering structure. This ordering structure associates with each element of the space a cone of preferred or of dominated directions. In case one considers an optimization problem where the images of the objective map are not only vectors but sets of vectors, one speaks of a set optimization problem. For defining optimal solutions of such a set optimization problem based on the so-called set approach one needs to find a way to compare sets based on the underlying variable ordering.

This talk aims thus at combining variable ordering structures with set relations in set optimization. We discuss the possible ways of doing that as well as several generalizations of well-known set relations used so far for partially ordered spaces. We analyze the properties of the introduced relations, we define new solution notions for set-valued optimization problems and compare them with other concepts from the literature. In order to characterize the introduced solutions a nonlinear scalarization approach is used. This can be the base for numerical procedures to solve such problems in practice.

4 - Metric (Sub)regularity of Composition Set-Valued Mappings with Applications to Optimization Problems with Variable Ordering Structure
Radu Strugariu

We discuss the (sub)regularity properties of composition-type multifunctions, with special emphasis on the sum case. Applications to fixed-point theory are provided. Furthermore, we analyze an optimality concept for set-valued optimization problems with respect to variable preferences, where the ordering structure is governed by a set-valued map acting between the same spaces as the objective multifunction. We present necessary optimality conditions for the proposed problem in terms of Bouligand and Mordukhovich generalized differentiation objects.

■ MC-26
Monday, 12:30-14:00 - John Anderson JA3.17 Lecture Theatre

Project Scheduling under Uncertainty

Stream: Scheduling with Resource Constraints
Invited session
Chair: *Massimiliano Caramia*

1 - A New Approach to Maximize the Expected NPV of a Project with Activity Duration Uncertainty
Stefan Creemers

We examine project scheduling with net present value (NPV) objective and stochastic activity durations. We use a Markov decision chain to structure the statespace and a backward Stochastic Dynamic Programming (SDP) recursion to calculate the maximum expected NPV of a project. Through a clever relaxation we are able to drastically reduce the size of the statespace. This allows us to optimally solve networks of up to 120 activities.

2 - Scheduling in Projects in Consideration of Uncertainties
Wolfgang Tysiak

In the context of how to handle uncertainties in projects, most of the OR textbooks still comprise a chapter about PERT. But unfortunately, it can easily be shown that the whole PERT approach systematically underestimates the real risk. Besides this, the PERT approach suggests and supports a fallacious and in a lot of cases simply wrong understanding of the underlying situation. The reason for this is mainly because PERT starts with the creation of a critical path, which assumes a strictly deterministic model, and then — like putting the cherry on the cake — just adds a few stochastic elements. But if you accept uncertainties, you get a total change in paradigm, because then everything becomes stochastic, let it be durations, buffers, dates of start and end of the activities etc. and even the critical path becomes a random variable. On the first sight this seems to be more complex than PERT, but the stochastic approach offers the opportunity to apply a lot of (uni- and multivariate) statistical tools. It is possible to analyse all these random

variables to get for instance an impression of the real "criticality' of the individual activities of the project and their correlations, their distributions etc. By this you get the opportunity to get a deeper insight into the real structure and dynamics of the project. The proposed contribution to the conference tries to show how to overcome the inappropriate PERT approach by means of Monte Carlo simulation.

3 - Project Scheduling with Uncertainty in Activity Execution Intensity
Massimiliano Caramia, Lucio Bianco

We study project scheduling with precedence constraints and unlimited resources. The latter problem, with the objective of minimizing the completion time of the project and deterministic activity durations, is known to be polynomially solvable. In the case of stochastic durations, the objective becomes to determine the project makespan distribution which is a #P complete problem. The most common technique used in this scenario is PERT. However, it is known that PERT tends to underestimate the expected makespan of a project. In our work, we try to overcome this by considering a stochastic formulation of the problem, exploiting the activity execution intensity as a stochastic variable, and a chance constrained optimization approach. The main hypotheses under which our model works are essentially two: one is related to having a sufficiently large time horizon for the project and the second, differently to what happens for the durations of the activities in the PERT model, is to assume a Beta probability density function for the activity execution intensity variables. The first hypothesis appears to be realistic since, when time horizon is large, stochastic factors tend to come into play in every decision problems; the second hypothesis, is realistic as well, since a minimum and a maximum value exist for the stochastic variables used in our model. Experimental results are presented.

■ MC-27
Monday, 12:30-14:00 - John Anderson JA3.27, Level 3

Stochastic Optimization and Energy Applications

Stream: Stochastic Optimization
Invited session
Chair: *F.-Javier Heredia*

1 - Valuation and operation of three types of power plants using continuous time stochastic control models
Rune Ramsdal Ernstsen

With the increasing focus on renewable energy in the deregulated energy markets, it is to be expected that the energy mix will change and along with it the dynamics of the energy prices. This will change the values of the existing and new power plants, and thus change the investment incentives. My research is based on valuation of three different types of power plants in a new electricity market: a renewable power plant, a conventional power plant and a storage power plant.

Typical examples of these types of power plants are wind, thermal and hydro power plants. The uncertainty in electricity prices, and in production input/output when it is relevant, is modelled using diffusion or Lévy processes.

In this talk I will briefly describe the calibration using an expectation maximization algorithm and give a heuristic derivation of the Hamilton-Jacobi-Bellman integro-differential equations that has to be solved to determine the value of the power plants. Finally I will present the three different problems that have to be solved for the three types of power plants.

The valuation models are used to assess the impact of conjectured future market conditions such as increasing or decreasing price trends, increased intensity and size of price jumps, and increased correlation between renewable production and electricity prices.

2 - Technical efficiency of thermal power units through a stochastic frontier

Jose Antonio Marmolejo, Roman Rodriguez Aguilar, Soledad Salazar

This work presents a model to obtain a stochastic frontier production function of a Mexican power generation company. The stochastic frontier permits evaluate the technical efficiency of an energy producer according of the level of the factor inputs. Electricity generation based on thermal generation is highly expensive due to operational inefficiency of thermal power plants. At the moment, in México, technical efficiency of thermal power units has not been studied for the national electricity system. Therefore, in order to know the productivity levels of thermal generation, an empirical application of the stochastic frontier model is obtained using a panel data for the period 2009-2013 of thermoelectric units from the Mexican electricity system.

3 - Parallel Proximal Bundle Methods for Stochastic Electricity Market Problems

F.-Javier Heredia, Antonio Luis Rengifo Núñez

The use of stochastic programming to solve real instances of optimal bid problems in electricity market usually implies the solution of large scale mixed integer nonlinear optimization problems that can't be tackled with the available general purpose commercial optimisation software. In this work we show the potential of proximal bundle methods to solve large scale stochastic programming problems arising in electricity markets. Proximal bundle methods was used in the past to solve deterministic unit commitment problems and are extended in this work to solve real instances of stochastic optimal bid problems to the day-ahead market (with embedded unit commitment) with thousands of scenarios. A parallel implementation of the proximal bundle method has been developed to take profit of the separability of the lagrangean problem in as many subproblems as generation bid units. The parallel proximal bundle method (PPBM) is compared against general purpose commercial optimization software as well as against the perspective cuts algorithm, a method specially conceived to deal with quadratic objective function over semi-continuous domains. The reported numerical results obtained with a workstation with 32 threads show that the commercial software can't find a solution beyond 50 scenarios and that the execution time of the proposed PPBM is reduced to a 15% of the execution time of the perspective cut approach for problems beyond 800 scenarios.

4 - Stochastic unit commitment with a rolling window to decrease uncertainty in islands

Victoria Guerrero Mestre, Javier Contreras

Over recent years, the electricity produced from renewable resources has experienced a large increase, representing an important percentage of the total electricity produced in many countries. The large share of renewable generation has promoted a big change in the way of scheduling power plants and operating electricity systems. The unit commitment (UC) problem aims at determining the schedule combination of the available power plants in order to satisfy the system consumption. As renewable generation increases, it becomes more difficult to schedule the generation and estimate the reserves. In isolated places, like islands, the influence of wind uncertainty on the operation is more pronounced.

This work models the UC problem for an isolated area with different generation technologies, such as thermal, wind and hydro power. This problem is modeled as a two-stage stochastic mixed-integer linear problem. The model aims to reduce the operational costs of the thermal units while satisfying technical constraints and finding the optimal amount of reserves. For that purpose, the schedules are updated so that the latest information about demand consumption and renewable forecast can be introduced into the optimization model. In addition, the start-up and shut-down of thermal units are modelled in detail to make the solution realistic.

■ MC-28

Monday, 12:30-14:00 - John Anderson JA3.26, Level 3

Problems on Risk Analysis and Logistics Situations

Stream: Allocation Problems in Game Theory and Some Problems on Inventory and Logistics Situations
Invited session
Chair: *Thomas Bjerring*

1 - Study Characteristics and in- and out-of-Sample Validity of Structured Expert Judgment Applications

Abigail Colson, Roger Cooke

Since the introduction of the classical model of structured expert judgment in the early 1990s, over 70 applications have been conducted to date, in fields as diverse as nuclear safety, volcanic risk management, and public health program evaluation. These studies form a valuable collection of data about expert judgment and the relative performance of equal-weight and performance-weight combinations of expert opinion. Previous work explores the in- and out-of-sample validity of performance-weight combinations, finding that performance-weighting outperforms equal-weighting both in and out of sample. We further that research by exploring the relationship between study characteristics (e.g., number of experts, number of seed questions) and in- and out-of-sample performance. We also examine the connection between in-sample performance and out-of-sample performance. We find the statistical accuracy of the best expert to be the best predictor of out-of-sample performance. This work can inform best practice guidelines to further improve the quality of future expert judgment studies.

2 - Consignment Contract for a Supply Chain of a Single Retailer and Competitive Manufacturers with Different Risk Attitudes

Yael Perlman, Tatyana Chernonog, Tal Avinadav

Consider n mobile application (app) developers selling their software through a common platform provider (retailer), who offers a consignment contract with revenue sharing. Each app developer simultaneously determines the selling price of his app and the extent to which he invests in its quality. The demand for the app, which depends on both price and quality investment, is uncertain, so the risk attitudes of the supply chain members have to be considered. The members equilibrium strategies are analyzed under different attitudes toward risk: risk-aversion, risk-neutrality and risk seeking. We show that the retailer's utility function has no effect on the equilibrium strategies, and suggest schemes to identify these strategies for any utility function of the developers. Closed-form solutions are obtained under the exponential utility function.

3 - Can Non-Parametric Risk Quantifiers Beat the Ancient Talmudic Asset Allocation Model?

Thomas Bjerring, Kourosh Marjani Rasmussen

The thought provoking paper by DeMiguel et al (2009) has sparked a heated discussion on whether modern model-based portfolio optimization adds any value over a simple equally weighted portfolio. In fact, anyone, introducing a new asset allocation strategy, should in our opinion, provide convincing evidence, that the strategy beats an equally weighted benchmark portfolio. In this paper, we discuss the use of non-parametric risk quantifiers in an optimization setting when constructing a portfolio of securities as an alternative to the equally weighted portfolio. We consider nine Exchange Traded Funds (ETFs) representing different sectors of the S&P500 and observe the performance of the equally weighted portfolio in the period 2002-2015. We then construct strategies with three different risk quantifiers, Conditional Value at Risk, Conditional Drawdown at Risk and Omega Ratio, all in a scenario optimization setting. We argue under what conditions such methods systematically provide extra information needed to beat the equally weighted portfolio and provide empirical evidence by performing a number of historical back tests.

■ MC-29

Monday, 12:30-14:00 - John Anderson JA4.12, Level 4

Data Analysis for Emerging Applications 3

Stream: Data Analysis for Emerging Applications
Invited session
Chair: *Seyhan Nisel*

1 - A bi-objective model for time-evolving clustering

Belen Martin Barragan, Emilio Carrizosa, Dolores Romero Morales

We address the problem of obtaining score-based clusters for time-evolving populations. We consider two objectives: the similarity of the so-obtained clusters to given reference clusters, and the smoothness of the clusters along the time horizon, both to be maximized. For particular cases of relevance, different solutions of the biobjective problem are generated in polynomial time and represented, allowing the user to select an appropriate trade-off between similarity to reference clusters and clustering smoothness. The methodology is applied to clustering Higher Education institutions in the United Kingdom tracking the satisfaction score of the annual National Student Survey.

2 - Determination of Factors Affecting the Classification of Countries in European Union by Cultural Similarities

Rauf Nisel, Seyhan Nisel

The importance of culture within the scope of economic and social development is today unanimously recognized in the European Union. According to European Commission, culture has been an utmost important aspect of human development for centuries, be it as an economic activity or as a potential for developing well-being and social cohesion. European Union culture policies aim to address and promote the cultural dimension of European integration. Aim of the study is to obtain a profile of countries in European Union in terms of their cultural characteristics and to determine which characteristics play significant role in the classification. Similarities of cultural characteristics were measured based on economic and social data, education, cultural employment, enterprises in cultural sectors, cultural participation, private cultural expenditure used also as classification criteria in the analysis. The data used in the analysis obtained from Cultural Statistics of Eurostat and different techniques of cluster analysis performed in order to obtain best solution in the classification. In our study we believe that determination of cultural characteristics playing significant roles in the classification of countries in EU will contribute to the promotion of the cultural dimension of European integration.

■ MC-30

Monday, 12:30-14:00 - John Anderson JA5.02, Level 5

Scheduling Satellites and Harbours

Stream: Scheduling Theory and Applications
Contributed session
Chair: *Maciej Machowiak*

1 - Exact and inexact scheduling algorithms for multiple earth observation satellites under uncertainties of clouds

Jianjiang Wang, Erik Demeulemeester, Zhimeng Li, Manhao Ma, Dishan Qiu, Dishan Qiu

Most earth observation satellites (EOSs) are equipped with optical sensors, which cannot see through clouds. Hence, many observations will be useless due to the presences of clouds. In this work, in order to improve the possibility of completing the tasks under uncertainties of clouds, we take the scheduling of each task to multiple resources into account and establish a novel non-linear mathematical model. To solve the problem efficiently under different scenarios, we propose an exact algorithm and some heuristic algorithms. With respect to the exact algorithm, which is inspired by Dantzig-Wolfe decomposition, we divide the complicated problem into a master problem and multiple subproblems, with a subproblem for each resource. A labeling-based dynamic programming algorithm is proposed to solve each subproblem. Afterwards, based on the solutions of the subproblems, we develop an enumeration algorithm to solve the master problem. Furthermore, we design five heuristics to solve the large-scale problems that generally fail to be solved by the exact algorithm due to the large space complexity. Experimental results show that the solutions of our model perform better than those of previous studies, and we also reveal the strengths and weaknesses of the proposed algorithms while solving different size instances.

2 - Optimization of crane moves in a real problem of mi niload AS/RS system

Ma Fulgencia Villa, Ramon Alvarez-Valdes, Greet Vanden Berghe, Tony Wauters

An Automated Storage and Retrieval System (AS/RS) is a type of warehousing system in which the store and retrieval activities are made by a crane without the interference of an operator. The AS/RS of the distribution company studied in this paper corresponds to the miniload type, in which each bin contains several small items. When an item is required, the corresponding bin is retrieved and transported to the picking zone, where the item is taken from the bin, and then the bin is stored again. Nevertheless, our problem has some special characteristics: the crane has a double shuttle and therefore it can move two bins at the same time, there are several picking zones of different sizes, the requests have different ready times and priorities, and the objective is to minimize the total weighted waiting time. We have developed two integer linear models for solving the problem. The first model requires that the destination of each bin is known in advance. Therefore, we have to solve first an assignment problem to determine the best positions for the bins. The second model determines simultaneously the destination of the bins and the route of the crane. As the computational results show that only small size problems can be solved with these models, we are developing heuristic algorithms for solving problems of realistic size.

3 - Moldable tasks in the berth and quay cranes allocation problem

Maciej Machowiak

The problem of good allocation quay cranes to the ships together with berth allocation problem has been studied. Since time of loading or unloading operation depends on a number of cranes allocated to a ship we use the model of moldable task. In the model we treated the ships as the tasks and quay cranes as the processors. Additionally, the processing speed of a task is considered to be a non-linear strictly increasing and arbitrary function of the number of processors allocated to it. To better allocation ships to the berths the bounds on the number of cranes has been introduced. Our goal was to find the schedule with minimum length. We present an approximation algorithm that obtains a feasible solution to the discrete version of the problem from the continuous version, i.e., where the tasks may require non integer number of the processors. We conducted a lot of computational experiments to show good average behaviour of the algorithm. Next we made the worst case analysis and show that the algorithm gives solution not worst than 2 of lower bound for the problem.

■ MC-31

Monday, 12:30-14:00 - John Anderson JA5.04, Level 5

Stochastic Modeling and Simulation 3

Stream: Stochastic Modeling and Simulation in Engineering, Management and Science
Invited session
Chair: *Frank Herrmann*

1 - Observations to Clearing Functions

Frank Herrmann

In production systems occur nonlinear relationships between lead times of orders and the system workload. Analytically, this can be evaluated by queueing theory. Missbauer (2002) relates the expected output to the expected WIP level in an M/G/1 queuing system (assuming steady state). For multiple-product job-shop production systems, a queueing network has to be analyzed. Missbauer (2002) shows that the dynamic behavior of such a production system should be modeled assuming non-stationarity. Building appropriate queueing models that handle both complex structures of the flow of material and non-stationarity is very difficult and often impossible (see Haskose et al., 2002). Consequently, several authors suggest an empirical or simulation-based approach to determine the expected or maximum throughput of a capacitated resource as a function of some measure of the WIP inventory (cf. Asmundsson et al.) and call this clearing function (cf. Missbauer and Uzsoy, 2011). Due to all these approaches, a certain functional shape of the final clearing function is assumed motivated either by queuing-theory results and/or — piecewise - by capacity limits.

2 - Minimizing supply disruption risk caused by natural disasters

Xiaojuan Wang, Wanshan Zhu

China has the most frequent earthquakes around the world. Nearly 800 times of strong earthquakes have occurred in China since the 20th century. Earthquakes may pose severe supply disruption risk to a manufacturer, which has hundreds of suppliers distributing in different parts of China. It is important for the manufacturer to allocate the order among the suppliers so that it minimizes the supply disruption risk caused by earthquake. The purpose of this paper is to present a useful way for quantifying the earthquake disruption risk and for helping the sourcing manager of the manufacturer to better allocate purchasing orders among suppliers. We assume that the manufacturer has multiple products and multiple suppliers. We then build a stochastic optimization model to formulate the manufacturer's order and the resulted earthquake disruption risks. To show the practice application of our model, we make a case study of an elevator manufacturer. Using its supplier data and the earthquake data from 1900 to 2014 in China, we analyze its supply disruption risk by numerical study.

3 - Competitive Analysis of the Storage Management Problem

Esther Mohr

Situations where price behavior is not stable, and hence the use of stochastic price models is difficult call for online models. The concept of online decision-making assumes that prices are revealed one at a time, and non-reversible decisions must be taken before the next price is seen. The objective is to maximize the overall profit. This work considers inventory management from the perspective of online algorithms. We assume the task is to find an optimal sales strategy. We employ competitive analysis, and derive an optimal online selling reservation price based on an a-priori known set of constants that bound the interday price volatility. This set-up differs considerably from traditional solutions to the inventory problem which make distributional assumptions about prices.

■ MC-32

Monday, 12:30-14:00 - John Anderson JA5.05, Level 5

AHP/ANP 03

Stream: Analytic Hierarchy/Network Process
Invited session
Chair: *Emel Aktas*

1 - Decision of Advertising Media Selection in the FMCG Industry

Canan Yesilyurt, Sebnem Burnaz, Y. Ilker Topcu

Decision of advertising media selection for a campaign is effected by many factors. Also sometimes these factors influence each other. At this context, it is important to have knowledge about which factors are more important and more impressive on selection decision. Since factors which affect this decision are dependent of each other, it is more difficult to make a decision. Therefore, ANP, one of the multi-criteria decision making methods similar to AHP but concurrently considers affection of factors, can help to make an advertising media selection decision where there are interrelations among factors. The purpose of this study is decide the most appropriate advertising media by evaluating and considering factors which affect selection decision by using ANP in the FMCG industry. In this study; first of all, factors which affect decision of advertising media selection are chosen, then integrations between factors are identified. According to integrations, factors are prioritized and Super Decisions software is used to analyze results. So, this study shows how to choose the most proper advertising media by considering factors which affects our decision.

2 - Analysing the Components of E-learning with DEMATEL and ANP

Yakup Celikbilek, Ayse Nur Adiguzel Tuylu

In recent decades, daily life components are quickened with technology, internet and other factors. So, e-learning programmes and courses have taken significant roles for universities and our daily lives with rising internet usage. Mostly, quickened daily lives obligate people to allocate less time for learning besides the any other important requirements. In today's world, companies which resist to technology, vanish day by day because of widespread adoption of technology. The competitive structure comprises e-learning programmes with the increasing number of them. Can an institution best with traditional learning methods coordinate the best e-learning without any alteration? What are the differences between the important factors of the traditional leaning methods and e-learning methods? Differentiated components of e-learning and their weights are getting more importance to boost and sustain an e-learning programme. This research is aimed to analyse the components of e-learning and their importance. With this perspective; first of all, the components of e-learning are defined and then the interrelationships among the components are construct with DEMATEL (Decision Making Trial and Evaluation Laboratory). After the interrelationships among the components and the network structure are determined, importance of the components are analysed with ANP (Analytic Network Process).

3 - Methodological Proposal for Strategic Decision Making at Mining Companies in Chile, based on the ANP and Aspects of Environmental Economics.

Alexis Olmedo-Navarro, Alejandro Caroca-Navarro, Tomas Gonzalez

The environmental problem not only affects the interests of individuals and society but also impacts the strategic decisions of organizations, to (Claver & Molina, 2000) environmental problems lead to threats of the environment in which it operates the organization, these threats can be, legislative pressures, market and finance related to respect and conserve the natural environment. The aim of this work is to develop a decision model to estimate the implication of the macro factors affecting the Environmental Economics and should be considered by organizations when designing their strategies from its mission and vision.With the prospect of environmental economics methodology for designing efficient strategies considering the aspects of the macro that affect organizations is proposed. To achieve this the ANP methodology used to establish a quantitative model to estimate the relative importance of each factor considering all the possible cause - effect generated between decision factors, finally integrate everything into a model that considers variables associated with strategic decision criteria mining companies. In a complex environmental context, organizations must conduct their efforts to develop coordinated strategies that are aligned with sustainability and corporate social responsibility from an environmental perspective, is why it is important to provide them with tools to design strategically and a focus on environmental economics linked to macro-strategies.

4 - A Decision Model to Assess the Interrelationships among the Logistics Performance Indicators

Berk Kucukaltan, Emel Aktas, Kevin Lu, Y. Ilker Topcu

Many indicators are used for measuring various aspects of company performance. However, deciding on which performance indicators to focus remains a tactical and an operational problem for managers. What is more, not all indicators have the same importance. That is why, multi-criteria decision making methods can serve an appropriate tool for identifying the priorities and level of importance of applicable performance indicators which should be presented in a balanced framework for a well-designed performance measurement model. Balanced Scorecard (BSC) is an established model for assessing performance based on financial and non-financial indicators. However, these indicators are not independent of each other and there is a need to apply a tool, such as the Analytic Network Process (ANP) which allows both direct and indirect relationships among the indicators. Hence, this study develops a framework for assessing performance indicators of the logistics industry based on the BSC. Then, it analyses the interrelationships among indicators using the ANP. The results of the analysis showed that the most important indicator is the educated employee and this finding explains that employee development play a significant role for logistics companies to provide better services and to be more competitive. So, the proposed model can help decision makers in logistics companies to decide on which performance indicators should be used to increase their competitiveness.

■ MC-33

Monday, 12:30-14:00 - John Anderson JA5.06, Level 5

Topics in Multiobjective Programming

Stream: Mathematical Programming
Invited session
Chair: *Tunjo Perić*

1 - A New Multiple Objective Integer Linear Programming Methodology for Vendor Selection and Supply Quotas Determination Problem
Tunjo Perić

In this paper a new methodology for vendor selection and supply quotas determination is proposed. The proposed methodology is contained of four phases: (1) Determination of criteria for vendor selection, (2) Application of AHP method to determine the objective function coefficients, (3) Forming multi objective integer linear programming (MOILP) model, and (4) Application the new multi objective integer linear programming method based on cooperative game theory in the MOILP model solving. The proposed methodology is tested on the example of flour purchase by a company that manufactures bakery products. The criteria used for vendor selection and quantities supplied by individual vendors are: (1) Purchasing costs, (2) Product quality, and (3) Vendor reliability.

2 - A New Iterative Method for Solving Multiobjective Fractional Programming Problem
Jadranka Kraljević, Tunjo Perić, Josip Matejas

In this talk we present a new iterative method for solving multiobjective fractional programming problem with an arbitrary number of decision makers. To solve the problem we transform it into the equivalent multiobjective linear programming problem and apply a new iterative method which was introduced in Josip Matejas, Tunjo Perić, A new iterative method for solving multiobjective linear programming problem, Applied Mathematics and Computation 243 (2014) 746—754. The final solution is obtained according to the principles of game theory. The aspirations of decision makers are respected within the frame of the given possibilities. The reality of aspirations are measured by the objective indicators and realization rates which are used to define the game strategy. The method is illustrated through several numerical examples.

3 - Goal Programming Methodology for Solving Multiple Objective Problem of the Technological Variants and Production Plan Optimization
Sead Resic, Zoran Babic

In this paper the goal programming method for solving multiple objective problem of the technological variants and production plan optimization has been considered. The optimization criteria are determined and the multiple objective linear fractional programming model for solving the problem under consideration is formed and solved. Furthermore, the analysis of the obtained results point out to the possibility of the efficient application of the goal programming method in solving the given problem.

■ MC-34

Monday, 12:30-14:00 - John Anderson JA5.07, Level 5

Nonlinear Programming Techniques

Stream: Nonlinear Programming
Invited session
Chair: *Ana Maria A.C. Rocha*
Chair: *Edite M.G.P. Fernandes*

1 - Biased random key grammatical evolution for function estimation
Ricardo Silva, Mauricio Resende, Jose Vianney Alencastro Jr., Otávio Silva

This paper presents a biased random key grammatical evolution (BRKGE) algorithm for the function estimation problem. The problem consists of finding a function that will best approximate a set of n-dimensional points given their output. Based on biased random key genetic algorithm, a variant of random-key genetic algorithms where one of the parents used for mating is biased to be of higher fitness than the other parent, our algorithm introduces a new random key encoding based on mapping process of grammatical evolution. Grammatical evolution is an evolutionary process that can create programs (in our case functions) in an arbitrary language. The production is performed using a mapping process governed by a grammar expressed in Backus Naur Form. The BRKGE algorithm was tested with several well-known symbolic regression instances from the literature. The results obtained were competitive in terms of objective function value and required computational time.

2 - Augmented Lagrangian methods for nonlinear programming with possible infeasibility
Leandro Prudente, Max Leandro Nobre Gonçalves, Jefferson Melo

We consider a nonlinear programming problem for which the constraint set may be infeasible. We propose an algorithm based on a large family of augmented Lagrangian functions and, accepting inexact global solutions of the subproblems, analyze its convergence properties taking into account the possible infeasibility of the problem. In a finite number of iterations, the algorithm stops detecting the infeasibility of the problem or finds an approximate feasible/optimal solution with any required precision. We present some numerical experiments illustrating the applicability of the algorithm for different Lagrangian/penalty functions proposed in the literature.

3 - A Self-Adaptive Penalty Firefly Algorithm for Constrained Global Optimization
Rogério B. Francisco, M. Fernanda P. Costa, Ana Maria A.C. Rocha, Edite M.G.P. Fernandes

This paper proposes a self-adaptive penalty function and presents a penalty-based algorithm for solving nonconvex constrained optimization problems. The global minimizer of the penalty function, subject to a set of bound constraints, is obtained by the firefly algorithm (FA), a swarm intelligence method inspired by the social behavior of fireflies and based on their flashing and attraction characteristics. We prove that the general constrained optimization problem is equivalent to a bound constrained problem in the sense that they have the same global solutions. To enhance the convergence of the FA, a local search procedure is invoked with a certain probability. The numerical experiments use a benchmark set of engineering design problems and show the effectiveness of the new self-adaptive penalty algorithm when compared with other penalty-based approaches.

■ MC-35

Monday, 12:30-14:00 - Colville C429, Level 4

DEA applications

Stream: DEA and Performance Measurement
Invited session
Chair: *Manolis Kritikos*

1 - Performance Evaluation Of Basic & Applied Research R&D Projects In Different Provinces of Iran With The Help of DEA
Mohamad Reza Rasol Roveicy

Most of Iranian R&D firms operating in the field pharmaceutical research ,offering technology intensive services that support the new drug R&D the process of client firm. The DEA analysis for evaluation efficiency of each units here the provinces dealing with R&D, it is important to pay special to the careful selection of inputs and outputs under the study.The purpose of this study has two folds, one evaluating R&D units with regard to basic research and another one ,with applied research background. The result of DEA can further be helpful in analyzing the National Innovation System of a country.

2 - Empirical Analysis of Total Factor Productivity Growth Trend in Agriculture, Energy, and Financial Sectors: A Malmquist Index Approach (analysis) of 20 SSA countries

Peter Nganga, Yukihiro Maruyama

The improvement of the total factor productivity is the inevitable requirement to realize healthy and robust development in Sub-Saharan African industries. In this study we examine levels and trends in agricultural, energy and financial sectors total factor productivity of 20 Sub-Saharan Africa (SSA) countries. We apply data from Eurostat input-output tables and our study covers 2001-2011, we use data envelopment analysis method (DEA) based to derive Malmquist Productivity Index. There is a good reason of measuring efficiency and productivity, measuring efficiency and productivity allows the separation of effects from those of the operating environment revealing the sources of efficiencies or productivity differentials, besides, identification and separation of controllable and uncontrollable sources of performance variation is essential both in private practices and public policy formulation for performance enhancement. The competitiveness and welfare level of people of any country are clearly related to its economic growth performance. Without economic growth there can be no long-term poverty reduction. While the findings demonstrate positive growth in TFPs, there is a cause of concern especially in agriculture TFP growth. Greater considerations must be given to future investment strategies and policy formulation and performance management.

3 - Ranking in Data Envelopment Analysis using a set of dummy Decision Making Units

Manolis Kritikos

We propose a procedure for ranking decision making units in data envelopment analysis, based on a set of dummy decision units. This paper proposes several new data envelopment analysis models by introducing the dummy decision units. The new models determine input and output weights for the dummy decision units and from the point of view of distances between the dummy decision units and normal decision units. As a result, we define a new common set of weights. Numerical examples are provided to illustrate the applicability of the new approach and the effectiveness of the new approach in DEA ranking.

■ MC-36

Monday, 12:30-14:00 - Colville C430, Level 4

OR Promotion among Academia, Businesses, Governments, etc. 1

Stream: Initiatives for OR Education
Invited session
Chair: *Oleksii Molchanovskyi*
Chair: *Yuliia Puzanova*

1 - Introducing OR for Multidisciplinary Environment: Ten Years' Experience of the Summer School AACIMP in Kyiv, Ukraine

Yuliia Puzanova, Oleksii Molchanovskyi, Dmytro Fishman, Olga Nazarenko, Kateryna Pereverza, Oleksii Pasichnyi, Gerhard-Wilhelm Weber

We will present our experience of successive development of the OR stream as a part of the Summer School AACIMP which is run in the National Technical University of Ukraine "Kyiv Polytechnic Institute" for already a decade. Initially it was organized as a single-stream event uniting lectures on various topics for students with different backgrounds. Later it became a multi-disciplinary platform for four simultaneous streams, including OR. Through these 10 years, we have changed topics and course design in order to try different approaches to introduce OR methods and tools for broad audience of the Summer School. e.g., in the latest version of the OR stream (2014), we had focus on both 'hard' and 'soft' OR techniques, including overview of methods for supply chain management, giving understanding of humanitarian (disaster relief operations) and commercial (global markets and international business) logistics, besides the stream courses covered the modern world economy and introduced behavioral aspects of OR for large socio-technical systems. Currently, the Summer School

is evolving as a cross-disciplinary project-based educational environment, with OR as an essential part of it, providing possibility to implement approaches from different fields in order to solve various problems, formulated by partner cities, companies and researchers. In addition we will discuss role of EURO & IFORS communities as important stakeholders of this initiative.

2 - Efficiency measurement and cross-country differences among schools: A conditional nonparametric approach

Jose Manuel Cordero, Daniel Santin, Rosa Simancas

The participation of the majority of nations on common international large-scale assessments like PISA has provided researchers with extensive cross-national databases that can be used to assess the performance of educational systems from a comparative perspective. Most cross-national studies usually apply econometric techniques to detect significant relationships between output and input variables, thus they do not consider the potential existence of potential inefficiencies in the performance of schools. In this paper we apply some recently developed frontier nonparametric methods to explore which are the main contextual factors in each nation that explain the existing divergences in school performance across countries. In particular we use the robust order-m to estimate efficiency measures of school performance, then we adapt the metafrontier framework to decompose the estimated inefficiency between two different levels (school and country). Finally, we use the conditional nonparametric approach to explore the potential influence of multiple factors at different levels (school and country) and incorporate their effect into the estimation of efficiency scores.

3 - Implementation of Participatory Decision Making Processes, to Determine the Actions of Conservation of Parrots and Green Macaw in an Ecological Reserve

Laura Plazola Zamora, Francisco Javier Sahagún Sánchez

In this work, a participatory decision-making strategy is designed to determine the most viable conservation actions to reduce the vulnerability of the populations of Parrot and green Macaw in a reserve of the biosphere, as well as to promote the appropriation of initiatives through the implementation of participatory decision making processes, in a context of environmental governance. To carry out the decision process, community workshops were organized and applied a quantitative tool of decision aid, which considered a criterion of equality between individuals. This required that individual's preferential information included not only a ranking of the alternatives, but also data on the strength of their preferences.

4 - Developing a Course on Crisis Management Using OR/MS Techniques

Brian Canlas Gozun, Francesc Miralles

When Super Typhoon Haiyan struck and ravaged the eastern part of the Philippines in November 2013, the country was caught off guard with the immensity of the disaster that brought about more than 6,000 deaths and thousands homeless. The devastation needed a staggering amount of rehabilitation, rebuilding and re-engineering. What then can government, non-government organizations, academe and businesses do in times of disasters and immediately after a disaster strikes? This study looks into how Operations Research / Management Science tools and techniques can be applied to a course on crisis management for undergraduate and graduate students as well as part of massive open on-line courses. This will be initially offered and tested in the Philippines given the country's history with natural disasters. One of the major topics would be humanitarian logistics since compared to universities abroad there is no such course in the country. Logistics was also one of the major problems in disaster recovery in the area where Typhoon Haiyan struck because it has been cut off from the rest of the country. This course would also go beyond the traditional boundaries of field and would be able to train both graduate and undergraduate students as well as practitioners in order to immediately help the most vulnerable in times of natural disasters and complex emergencies using OR/MS tools and techniques.

■ MC-37

Monday, 12:30-14:00 - Colville C411, Level 4

Optimization for Sustainable Development 3

Stream: Optimization for Sustainable Development
Invited session
Chair: *Herman Mawengkang*
Chair: *Gerhard-Wilhelm Weber*

1 - Optimization Model for Water Distribution Network Problem Under Uncertainty

Asrin Lubis, *Herman Mawengkang*

One fundamental issue regarding to the increase of population correlated to the increase of industrial and agriculture activities has motivated the need for a more rational use of water resources. A well planned of water resources development, their distribution, and their utilization has been put forward for research, particularly in North Sumatra Province, Indonesia. This type of plan belongs to the management of what is called Water Resources Management (WRM). Water treatment and distribution is undoubtedly of high priority to ensure that communities could gain access to safe and affordable drinking water. Therefore the distribution network should be designed systematically. We propose a nonlinear stochastic optimization model for tackling this problem under the consideration of reliability in water flows. The nonlinearities arise through the pressure drop equation. We adopt sampling and integer programming based approach for solving the model. A direct search algorithm is used to solve the integer part.

2 - Hospital Capacity Planning Problem Under Uncertainty

Suryati Sitepu

For people, particularly, those who live in big cities, in Indonesia, the demand to get health service is increasing. Even though the number of hospitals are getting more and more, still there are more and more people who seek health care from neighbor countries.. Undoubtedly, the urgent need to tackle this situation is to improve health service performance in hospitals. All operations related to the health service performance in hospitals are limited in terms of capacity. Therefore, in order to fulfill the patients' demand for health care, the hospitals management should have a plan for the capacity of the operation. In hospitals, capacity planning is concerned with making sure of balancing the quality of health care delivered with the cost of providing that care. Such planning involves predicting the quantity and particular attributes of resources required to deliver health care service at specified levels of cost and quality. The fundamental measure of hospital capacity planning is the number of inpatient beds accordingly the number of doctors and the number of nurses. This paper presents a capacity model under uncertainty that gives insight into required nursing staff capacity and opportunities to improve capacity utilization on a ward level. The capacity model, formulated as a stochastic programming problem, is developed to calculate required nursing staff capacity. We use a scenario-based approach for solving the model.

3 - Optimization Model for Hazardous Waste Management of the Oleo Chemical Industry

Rusli Tan, *Herman Mawengkang*

Hazardous waste may include any materials that is potentially harmful due to its ignitability, corrosivity, reactivity, or toxicity. These hazardous wastes are usually generated by a large industrial plants, such as, oleo chemical. The management of hazardous waste consists of collection, transportation, treatment, and disposal. This paper addresses a multi objective integer programming model, which includes minimizing operational cost, transportation risk and disposal risk. We develop an interactive approach for solving the model. The result model can be used to support sustainable chemical industries.

4 - An integer programming model for sustainable multi-product fish production planning problem

Devy Mathelinea, *Herman Mawengkang*

A multi-product fish production planning produces simultaneously multi fish products from several classes of raw resources. The sustainable production planning problem aims to meet customer demand subject to environmental restrictions..The production planning problem aims to fulfill production and sourcing decisions so as to meet customer demand subject to production capacity, workforce availability and inventory restrictions and is inherently an optimization problem. Therefore it has become a significant economic force in remote and rural coastal communities, particularly in North Sumatra province of Indonesia The objective of the problem is to minimize the total cost or to maximize profit. This paper considers the management which performs processing fish into several seafood products. An integer programming model is proposed to model the problem. Direct search approach based on activity constraints strategy is used for solving the model. A real world problem from North Sumatra province is presented.

■ MC-38

Monday, 12:30-14:00 - Colville C410, Level 4

Coordination and Cooperation in Humanitarian Supply Chains

Stream: Humanitarian Applications
Invited session
Chair: *Tina Wakolbinger*

1 - An Integrated Disaster Relief Supply Chain Network Model with Time Targets and Demand Uncertainty

Amir Masoumi, *Anna Nagurney*, *Min Yu*

As the number of natural disasters and their impacts increase across the globe, the need for effective preparedness against such events becomes more vital. In this research, we construct a supply chain network optimization model for a disaster relief organization in charge of obtaining, storing, transporting, and distributing relief goods to certain disaster-prone regions. Our system-optimization approach minimizes the total operational costs on the links of the supply chain network subject to the uncertain demand for aid at the demand points being satisfied as closely as possible. A goal programming approach is utilized to enforce the timely delivery of relief items with respect to the pre-specified time targets at the demand points. A solution algorithm for the model is also provided. A spectrum of numerical examples illustrates the modeling and computational framework, which integrates the two policies of pre-positioning relief supplies as well as their procurement once the disaster has occurred.

2 - Integrating disaster management capabilities and pre-positioning inventory

Gerald Reiner, *Nathan Kunz*, *Christian Wankmüller*

Disasters affect millions of people worldwide. Efficient and effective logistics is required to answer timely to their pressing needs. Different strategies exist to prepare for disasters before they occur. These strategies significantly reduce the response time to reach victims, e.g., prepositioning life-saving relief supplies in disaster prone areas as well as investing in disaster management capabilities (e.g., process management). Kunz et al. (2014) demonstrated that these two preparedness strategies provide the best results when used together. This model considered a basic setting in which a relief organization prepositions inventory in every disaster prone country, i.e., the response time is assumed to be zero and there arent any transport times considered. In reality, such inventories are pooled in regional warehouses and serve a number of different countries. This extension of the model requires including transport times between warehouse and location of the disaster. Even in case of prepositioning inventory, delays due to customs processes have to be considered if there are cross-border deliveries. We expect to provide a new insight into the proper balance between different preparedness strategies. In particular we will carry out sensitivity analysis to explore the influence of transport distance in combination with cross-border transport on disaster response performance. A dynamic model will be developed to enable the described analysis.

3 - Disaster relief inventory management: horizontal cooperation between humanitarian organizations

Fuminori Toyasaki, *Emel Arikan*, *Ioanna Falagara Sigala*,
Lena Silbermayr, *Werner Jammernegg*

There has been increased interest in the cooperation between the humanitarian organizations (HOs). Our research focuses on the case of horizontal cooperation in inventory management that is actually implemented in the United Nation Humanitarian Response Depots

(UNHRD) network. Our research follows a two-step research approach, which combines collection of empirical data and quantitative modeling. Within the UNHRD network, the World Food Program (WFP) acts as the service provider for the humanitarian community on a non-profit basis. The UNHRD offers to its member's standard for free services such as storage, warehousing and stock management. It also prepares unbranded back up stocks (white stock and virtual stocks). Real-time stock visibility offered by the UNHRD to all members helps them to exchange stocks (stock swaps). Through a series of the interviews, we identify several managerial issues for sustainable cooperative inventory management that the UNHRD network pursues. We develop a news-vendor model to analyze the inventory collaboration network of the UNHRD in the context of non-cooperative game theory. Specifically, referring data of a member of the UNHRD network, we seek to explore member HOs' incentive of joining the network, coordination mechanism that achieves a system optimum, impacts of the members' decision about stock rationing between the UNHRD's and members' own warehouses on optimal operations of the network.

4 - Toward the resiliency of humanitarian cooperation: examining the performance of horizontal cooperation among humanitarian organizations using an agent-based modeling
Junko Mochizuki, Fuminori Toyasaki, Ioanna Falagara Sigala

This study proposes a multi-agent simulation model to examine how different operational environments and incentive mechanisms may affect the collective performance of complex humanitarian response system. Using the UN Humanitarian Response Depot (UNHRD) system as an example, a stylized model of one service provider, two member organizations and multiple humanitarian crises is developed to illustrate the changing uses of four alternative relief goods sourcing options namely: i) own storage for own items ii) UN storage for own items iii) stock-swaps and iv) white stock uses. Under the plausible assumption that the past success of sourcing options influence member organizations' future resource allocation, the model indicates that the additional buffer stock capacity offered by horizontal cooperation induces undesirable system dependency: while it gives member organizations more flexibility to meet highly stochastic demands under uncertainty, it also encourages them to store less of their own relief goods as a result. This tendency was particularly notable under the flexible budgeting regime, highlighting the further need to understand and evaluate the details regarding decision-making heuristics of individual member organizations.

■ MC-39

Monday, 12:30-14:00 - Colville C405, Level 4

Organizational Decision Processes

Stream: Decision Processes
Invited session
Chair: *Jeffrey Keisler*

1 - How to schedule employees' vacations cost-efficiently and unbiased, when the minimum demand for working employees varies between and within seasons?
Antti Punkka

In some industries, forecasted minimum demand for personnel varies from season to another, the maximum (non-overtime) workload per employee can differ between periods for which shifts are planned, compensatory personnel is not available, and recruitment requires a long training period for a class of new employees. We discuss how operations research can be used to support cost-efficient scheduling of employees' vacations for one calendar year. This process is further complicated by several conditions set by collective bargaining and law, the need for unbiased and fair treatment of employees in various aspects, and the goal of acknowledging employees' wishes on their vacation schedule. We develop a MILP model to solve the above-mentioned problem and discuss how the model will be applied to schedule vacations of some 1000 employees in 26 depots in Finland.

2 - Creating common languages for logical organizational decision processes
Jeffrey Keisler, H Jerome Keisler

We consider a network of agents, each endowed with a vocabulary and a knowledge base in first order logic, and perhaps a set of possible new observations that may be added to the knowledge base. Agents can prove facts from their knowledge bases. An agent with a reporting relationship to another agent can communicate facts within their common language. A decider agent needs to determine whether an option is correct or which one of a set of alternatives is correct. Mathematical results from our 2012 and 2014 papers identify verifiable conditions for which the networks are rich enough to ensure that the decider will succeed, and whether a finite plan can be prepared in advance of the new observations. An important interpretation of this framework is that of an organization which aims to construct decision analytic models to combine contributions from different experts, stakeholders and consultants in order to guide decision makers. We develop the interpretation and relate it to challenges in decision consulting, such as: creating operational definitions to be shared by some, or all, participants in the decision process; involving and communicating with different players at different stages of the analysis; and framing decisions in anticipation of requisite models.

3 - Decision Analysis Agents in a Cognitive Boardroom Environment
Debarun Bhattacharjya, Jeffrey Kephart

The burgeoning role that machines play in helping us make decisions is bound to spill over into organizational decision processes. Interactions and engagements in human-machine symbiotic relationships will be common place and will likely increasingly occur in a sophisticated yet natural fashion. In this talk, I will present aspects of ongoing work on building a cognitive boardroom environment with a number of agents that are based upon decision analysis principles, designed to improve the quality of high-stakes decisions. People interact with the room and the multi-agent system in the environment using speech and gestures. I will present a select few agents, focusing on those based on decision analysis, and try to show how the room could enable decision makers to make better decisions in the context of high-stakes decisions. One of the applications we have pursued so far is around the domain of mergers and acquisitions.

Time permitting, I will also discuss some findings pertaining to decision analysis modeling. Complex real-world decisions typically involve the use of a variety of models, built by people with a diverse set of skills across domains. Due to computational complexities, often several approximations are necessary for efficient evaluation and analysis. I will try to share some insights we have gleaned from comparing the impact of various aspects of decision analysis models, with the help of an illustrative example.

4 - Idea Generation and Idea Execution
Kevin McCardle

We develop a stochastic dynamic programming model of a researcher who can spend her time in one of two activities: generating a new idea or working on an existing project. There is a prior probability that any idea can be successfully completed; that probability is updated as work on the project ensues but success does not arrive. The question is when to quit working on a project and turn attention to generating a new idea. One goal of the paper is to make endogenous the opportunity cost of not generating a new idea while working on the current project. We consider several variants of the model: discrete versus continuous time, finite versus infinite horizon, single versus multiple projects, single versus multiple rewards, zero versus non-zero fixed costs, and risk neutral versus risk averse. This is joint work with Ilia Tsetlin and Bob Winkler.

■ MC-41

Monday, 12:30-14:00 - Colville C512, Level 5

MCDA and Environmental Management I

Stream: Multiple Criteria Decision Aiding
Invited session
Chair: *Antonio Boggia*

1 - A new tool for sustainability assessment in geographic environment: GeoUmbriaSUIT

Luisa Paolotti, Gianluca Massei, Lucia Rocchi, Roberta Calio', Cecilia Ricci, Paolo Stranieri, Antonio Boggia

This paper is aimed to present the new tool GeoUmbriaSUIT. GeoUmbriaSUIT is a QGIS plugin for sustainability assessment in geographic environment, using multiple criteria — i.e. environmental, economic and social. The plugin works in QGIS, a free and open source geographic software, widely used in several fields. It implements the algorithm TOPSIS, which defines a ranking based on distance from the worst point and closeness to an ideal point, for each used criteria. Entry of weights can be done directly, if known, or with the use of a pairwise comparison table. The outputs of geoUmbriaSUIT are both geographic and graphic. The first shows the maps of the multicriteria analysis results for each elementary area analyzed (e.g. countries, regions or municipalities). The graphic output shows the value of sustainability, with the use of bars, bubbles and points. The numerical output is the "sustainability index', given from the linear combination of three different indexes: environmental index, economic index and social index. The higher is the value of those indexes, the better is the performance of a single "research unit'. Moreover, the plugin implements the DOMLEM algorithm based on the Dominance Based Rough Sets' theory. With its use the transparency, the analysis and the back analysis capability are extremely increased. An example of application, using indicators at regional level, is here presented.

2 - Geographic MCDA for sustainability assessment: the new tool VectorMCDA

Lucia Rocchi, Gianluca Massei, Luisa Paolotti, Antonio Boggia

The aim of this paper is to present the new tool VectorMCDA. VectorMCDA implements some multicriteria decision analysis (MCDA) algorithms using vector data in QGS GFOSS software. VectorMCDA assumes that each geographical object, described with a record in the attribute table, is a single alternative (geo-alternative) and the algorithms implemented in the plugin analyze the attributes, elaborate these ones like criteria and return the output in one or more columns, added in the attribute table. The output are shown as geographic maps in QGIS canvas and in a graphical html page. The algorithms available in the current VectorMCDA version are the following: geoWeightedSum - implementng the classic weighted sum algorithm; geoTOPSIS - implementing the ideal point algorithms based on TOPSIS model; geoFuzzy - implementing the fuzzy MCDA model and returning the fuzzy intersection and fuzzy union MCDA indexes; geoConcordance: calculating the concordance and discordance indexes for each geo-alternative, as a reference for assessment through Electre models family; geoPromethee - implementing the Promethee method in a geographic way; geoRSDB - the module implements the DOMLEM algorithm for Dominance based Rough Sets theory. The current implementation of the module is "discovery knowledge oriented', instead of a proper MCDA algorithm; geoXMCDA - is the first implementation (still under development) of xMCDA standard for allowing MCDA data interoperability.

3 - Multicriteria Spatial Decision Support Systems for Assessing Sustainability in Rural Parks: An Application of Geo Umbria Suit Model

Giovanni Ottomano Palmisano, Kannan Govindan, Annalisa De BONI, Rocco Roma

Rural sustainable development (RSD) is a very important topic under European Union's Common Agricultural Policy (CAP). Also, the topic under study is complex in terms of interactions between natural resources, agricultural productions and local communities. In RSD, assessing the rural sustainability is a difficult decision making process due to the spatial dimension of rural areas, the multidimensional concept of rural sustainable development and the conflictuality between different objectives. Therefore, there is a need to utilize a Multicriteria Spatial Decision support System (MC-SDSS) tool for assessing rural sustainability which supports the policy makers for addressing the financial interventions to specific rural areas for improving their sustainable development. In specific context of RSD, sustainability assessment of rural parks is a challenging issue, because most of the rural parks aim to promote sustainability by reconciling different and conflictual objectives, such as protection of natural resources, enhancement of historical and cultural heritage, promotion of local food products, as well as employment and income generation in agricultural sector. In our research, we assessed rural sustainability of Alta Murgia National Park (Apulia Region, Southern Italy) by applying "Geo Umbria Suit' MC-SDSS model (Massei e Boggia, 2014). The results were synthetized in a sustainability ranking of the municipalities belonging to this rural park.

4 - Evaluation in urban planning: an integration between MCDA and GIS for the Operational Urban Plan of Cava De' Tirreni (Italy)

Pasquale De Toro, Silvia Iodice

The aim of the paper is to provide a support to evaluation in planning through an application based on the proposal of the Municipal Urban Plan of Cava de' Tirreni (province of Salerno, Italy). The goal is to elaborate a Support Decision System to evaluate the landscape and territorial integration of possible alternatives of Operational Plans, which are usually formed after public announcements to select, in a competitive way, the interventions to be implemented in transformation areas. Starting from the concept of landscape areas that divide the municipal territory, it is examined the way the urban plan is articulated; it is indeed formed by a dynamic interaction of analytical and conceptual components. The proposed procedure helps the selection of the first Operational Plan, characterized by the best grade of coherence with the Urban Plan prescriptions , choosing three different urban areas for the experimentation application. The study is articulated in tree steps: 1) check of conformity; 2) economic and financial feasibility, and 3) performance of the plan actions; in this way a first selection of the projects that best follow the established standards can be lead, taking into account a suitable system of indicators (urban, economic, ecological and social ones) through which verify the goals achievement. The evaluation has been carried by means of integration between MCDA and GIS.

■ MC-43

Monday, 12:30-14:00 - McCance MC303, Level 3

Defence and Security Applications III

Stream: Defence and Security Applications
Invited session
Chair: *Ana Isabel Barros*

1 - Managing Public Opinion While Fighting Terrorism

Gustav Feichtinger, Jonathan Caulkins, Dieter Grass

The key innovation in this two-state optimal control model is to presume that the outflow from the stock of terrorists is increasing in the level of public sympathy for those operations, as well as in the level of counter-terror efforts. The reason for this is that public support encourages the civilian population, within which the terrorists are embedded, to provide information or otherwise assist the counter-terror forces, or at least to refrain from actively helping the terrorists.

The analysis yields interesting results, both mathematically and substantially. We find a Skiba curve separating different regions in state space, for which it is optimal to drive the system to steady states with either a lower or a higher number of terrorists. There are places in the state space where a slight increase in the initial number of terrorists can tip the optimal strategy, from approaching the lower-level to approaching the higher-level of terrorists.

In the second part of the paper the existence of persistent oscillations is shown. Hopf and Bautin bifurcations occur. The latter generates a phase portrait in which a stable limit cycle coexists with a stable fixed point providing a nice interpretation of the solution. The unstable cycle in between acts as separatrix between two basins of attraction.

2 - Security Planning

Ana Isabel Barros, Axel Bloemen, Dennis Huisman, Martin van Meerkerk

Surveillance, reconnaissance and security operation planning incorporates several practical challenges like how to collect information or respond to security requests with different priorities at given locations and time windows, using different types of assets and facing uncertainty in the handling time and travelling time between the different locations? We introduce an extension of the stochastic team-orienteering problem to tackle this problem and a fast approach to develop robust assignment and routing plans that explicitly take uncertainty into account.

3 - Conflict Contagion — Predicting internal conflicts
Tom Clarke

With an increased emphasis on upstream activity and Defence Engagement, it has become increasingly more important for the UK Ministry of Defence (MOD) and government to understand the relationship between conflict and regional instability. As part of this process, the Historical and Operational Data Analysis Team (HODA) in Defence Science and Technology Laboratory (Dstl) was tasked to look at factors that influenced the regional spread of internal conflicts to help aid the decision making of government. Conflict contagion is the process by which a conflict in one state (State A) influences the outbreak of conflict in another state (State B). The aim of the task was to produce a tool that could predict the likelihood of conflict contagion based upon a set of numerical variables. This paper will describe how we conducted this task through a quantitative study of a selection of contagion and non-contagion case studies. We looked at a set of 14 variables that covered structural, political, socio-economic and cultural factors of both States A and B. All case studies took place after the end of the Cold War. We will discuss the range of statistical methods we used on our dataset, in particular the challenges arising from a dataset containing both binary and continuous data. Progress towards the ultimate aim will also be discussed, together with the outstanding issues that still need to be tackled.

■ **MC-44**

Monday, 12:30-14:00 - McCance MC319, Level 3

Neural Networks and Applications

Stream: Fuzzy Decision Support Systems, Soft Computing, Neural Network
Invited session
Chair: *Hans-Jörg von Mettenheim*
Chair: *Georgios Sermpinis*

1 - Locally Weighted Krill Herd Support Vector Regression and Adaptive Market Hypothesis: Evidence from the Exchange-Traded Funds
Charalampos Stasinakis, Georgios Sermpinis

The motivation of this paper is two-fold. Firstly, a locally weighted Krill Herd - Support Vector Regression (KH-SVR) model is introduced, which embodies a novel meta-heuristic optimization method inspired by the herding of krill swarms. Secondly, the study aims to provide evidence to support that the degree of market efficiency is related to the market enviroment and the evolutionary adaptability of its participants, as the Adaptive Market Hypothesis (AHM) suggests. In order to achieve that, the KH-SVR is applied to the task of forecasting and trading several ETF stocks on a daily basis over different horizons within the last financially volatile decade. Its statistical and trading performance is benchmarked with traditional SVR structures and parameter optimization methodologies. As it turns out, the KH-SVR outperforms all the other counterparts in terms of statistical and trading efficiency. The results also provide strong findings that are consistent with the implications of the AMH, such as eroding time-varying returns and their high dependence on market conditions.

2 - Forecasting Residual Prices in the Automotive Industry with Artificial Neural Networks
Hans-Jörg von Mettenheim, Christoph Gleue, Dennis Eilers, Michael H. Breitner

It is common in the automotive industry that a significant share of vehicles is leased and not sold. In the case of leasing the residual value of the vehicle is typically fixed in advance. This necessitates and accurate estimation of the resell price of the vehicle in three to five years.

A precise forecast is of relevance, because both deviations to the upside and the down-side are potentially economically bad. Estimating too low a residual value leads to higher leasing rates. This may put the vehicle in a competitive disadvantage. On the other hand, a high residual value estimate leads to low leasing rates but also presents the risk of not being able to resell the vehicle at this price, thus leading to losses in the future.

Here, we show how an artificial neural networks with only few inputs leads to acceptably accurate forecasts of residual values.

■ **MC-45**

Monday, 12:30-14:00 - Graham Hills GH514 Lecture Theatre

Train Path Planning and Rolling Stock in Rail Transport Networks

Stream: Optimization of Public Transport
Invited session
Chair: *Jens Opitz*
Chair: *Peter Großmann*

1 - Maximisation of homogenous rail freight train paths at a given level of quality
Michael Kümmling, Peter Großmann, Jens Opitz

Increasing demand of rail freight transport requires the optimal utilisation of capacity on existing railway lines. However, a certain quality has to be maintained for each freight train path as well. We provide extensions to our freight train paths optimization model to maximise the number of freight train paths at a given level of quality. Additionally, we present different techniques to achieve homogenous train paths.

2 - A novel approach for optimized planning of rail freight train paths with intersecting traffic flows
Daniel Pöhle, Reyk Weiß

Today, capacity planning of railway traffic is a complex and time-consuming task. Due to the high number of influences on rail capacity — passenger and freight trains as well as construction sites — , timetable optimization in the railway network cannot be efficiently handled with manual effort. For a timetable-based development of railway infrastructure, freight train paths are optimized based on a future operating program for passenger trains to detect bottlenecks in the infrastructure. Rail freight train paths are optimized on predefined tracks, called construction parts, which have many mutual dependencies through the use of the same infrastructure due to the highly intermeshed German railway network. For that reason the planning problem gets significantly more complicated and is too hard to be solved to optimality with manual effort. In this work, a novel approach for optimized planning of rail freight train paths will be presented and discussed. The approach combines automated periodic timetabling, optimized train path assignment and an innovative extended PESP model in the optimization process and produces either a valid rail freight timetable or a source for infeasibility, which is interpretable for a timetabling professional.

3 - A Matheuristic Approach for Solving the Railroad Hump Yard Block-to-Track Assignment
Richard Lusby, Jørgen Thorlund Haahr

This paper presents a novel matheuristic for solving the Hump Yard Block-to-Track Assignment Problem. This is an important problem rising in the railway freight industry and involves scheduling the transitions of a set of rail cars from a set of inbound trains to a set of outbound trains over a certain planning horizon. The proposed approach decomposes the problem into three highly dependent subproblems. Optimization-based strategies are adopted for two of these, while the third is solved using a greedy heuristic. We demonstrate the efficiency of the complete framework on the official datasets, where solutions within 4-14% of a known lower bound (to a relaxed problem) are found. We further show that improvements of around 8% can be achieved if outbound trains are allowed to be delayed by up to a maximum of two hours in the hope of ensuring an earlier connection for some of the rail cars.

4 - Risk based maintenance planning of railway rolling stock critical systems
Babakalli Alkali

The increase in the number of railway rolling stock in-service failures, delays and service cancellations has been a major challenge in the railway industry. These events as a result contribute to the reduction of the overall performance and reliability of the train fleet services. The planning of maintenance activities is a very important strategy to guarantee some level of effective operation of railway passenger services. The risk based maintenance approach is a common tool that is used for planning of maintenance activities. This paper investigates defects of a specific train units leading to incidents such as delays, part and full cancellations of services. The door systems are considered to be critical

systems as they consist of several worn and aging components which are stochastically independent. However, preventive maintenance policy makes the door component functionally dependent. A probability approach is considered and the maintenance activities are prioritised based on risk. The expected time of failure is based on the risk and uncertainties. Preventive maintenance optimisation is performed using a cost function, which involve incorporating the average number of door components replaced over some finite horizon. A numerical assessment of the door system components is conducted in a view to adequately support the planning of maintenance of the critical systems.

■ MC-48

Monday, 12:30-14:00 - Graham Hilils GH510, Level 5

Facility Location and Location in Graphs

Stream: Location
Contributed session
Chair: *Sergio García Quiles*

1 - Multi-Stage Location of Flow Intercepting Portable Service Facilities

Antonio Sforza, Annunziata Esposito Amideo, Claudio Sterle

The multi-stage flow intercepting facility location problem (MS-FIFLP) is a tactical and operational decision problem arising when portable facilities have to be located and dynamically re-located on a network according to its conditions, expressed in terms of flow parameter values, varying on a multi-stage time horizon. The location of such facilities is particularly relevant in many application fields, such as, among others, urban traffic management, network monitoring and control, urban security, where it is fundamental to take into account the uncertain nature of the phenomena under investigation. The aim of MS-FIFLP is to maximize the flow intercepted by the facilities (or to minimize the number of used facilities) and minimize the relocation cost associated to them. For its solution we propose a sequential and an integrated approach, both based on ILP formulations. The choice between them has to be done considering the specific features of the problem under investigation and depends also on the kind of the available data. The two approaches have been experienced on test networks derived from a real case study. The emerging results confirm their effective usage for several flow intercepting facility location problems encountered in real applications.

2 - Location of Units in a Data Network with Full Reliability and Redundancy

Lukas Matthias Schäfer, Sergio García Quiles, Andreas Mitschke, Vassili Srithammavanh

This talk addresses the problem of designing a data network in a predefined space. The network has to fulfil given features and restrictions while being optimal in certain criteria. Features are data flows between certain units, and full reliability and redundancy of the network. A network is fully reliable if the probability of the network failing any given function has to be less than a fixed safety threshold and full redundancy means that no single failure should lead to the loss of any given function. Restrictions can for example be connection requirements between certain units or certain unit placement restrictions in the specified space. Optimality criteria can be as easy as the weight and the cost of the network or can be extended to include the energy consumption and response time of the network. The problem of designing the network is then to decide where to locate the units while fulfilling all needed features and restrictions. Our approach to the problem is to view the given pre-defined space as a digraph where the nodes are possible positions for the units of the network and the edges are possible cable connections. The problem can then be formulated as a unit location problem which has to fulfil given flows with multiple start and end nodes, full reliability, full redundancy constraints and can be optimized over different objectives. This formulation results in a mixed integer non-linear programming problem with non-linearity in continuous and binary variables.

3 - An Enhanced Implementation on Drezner's Exact Method

Becky Callaghan, Said Salhi, Gábor Nagy

The p-centre problem is a well know location problem that wishes to locate p desirable facilities, such as hospitals, amongst n demand points such that the maximum distance from a demand point to it's allocated facility is minimized. This paper extends an idea, originally proposed by Drezner, where a smaller subset of potential facility locations are found. This then decreases the problem size dramatically and so solution values for larger, more complex data sets can be found. It analyses the original iterative algorithm, and initial testing on larger data sets gives promising results. The paper then proceeds to enhance the algorithm so that the overall computational time is greatly decreased.

4 - The P-Median Location Problem with Stochastic Costs

Sergio García Quiles, Laureano Fernando Escudero

The p-median problem is one of the most classical problems in Discrete Location and consists on choosing p locations and assigning the other locations to these p medians so that total allocation cost be minimum. Here we study how to solve this problem when the costs are uncertain: a radius based formulation is developed to model the minimization of the expected cost over a set of scenarios at the same time that a set of first order stochastic dominance constraints are required to reduce the risk on the cost due to non-wanted scenarios. A computational study is provided

■ MC-49

Monday, 12:30-14:00 - Graham Hills GH511, Level 5

Local Search Methods and Evolutionary Algorithms

Stream: Metaheuristics
Invited session
Chair: *Manuel Laguna*

1 - Empirical Evaluation of Dual Local Search Enhancement Techniques

Mona Hamid, Jamal Ouenniche

Routing problems have been at the origin of the design of many optimal and heuristic solution frameworks such as branch-and-bound algorithms, branch-and-cut algorithms, classical local search methods, metaheuristics, and hyperheuristics. In this research, we empirically investigate the value added of local search enhancement techniques in a dual search framework customized for solving the traveling salesman problem. Computational results support the effectiveness and/or efficiency of performance of enhancement tools; however, the extent to which they perform seems to depend on the problem structure.

2 - Water distribution network design optimisation using iterated local search

Annelies De Corte, Kenneth Sörensen

A water distribution network aims at transporting drinking water from one or more resources to multiple demand nodes via a looped network of pipes. The objective of the water distribution network design optimisation problem is to find the optimal pipe configuration out of a discrete set of available pipe types, taking into account hydraulic principles, energy laws, material customer requirements. A metaheuristic technique, called iterated local search, is used to tackle this challenging combinatorial optimisation problem. A lot of research has been conducted on this mixed-integer, non-linear optimisation problem in the past. In contrast to previous research, where algorithm testing was limited to some small benchmark instances, the authors test the iterated local search algorithm on a broad, real-life set of test instances, generated by HydroGen. A full-factorial experiment was conducted to find the best algorithm configuration and parameter settings.

3 - Scheduling The Blocking FlowShop Problem With The Artificial Bee Colony Algorithm

Nouha Nouri, Talel Ladhari

In this work, we consider the blocking permutation flowshop scheduling problem. Under such issue, there are N jobs to be processed on a set of M machines in a unique order. There are not intermediate queues of jobs between successive machines due to the zero capacities of the

intermediate buffers. Hence, a job cannot leave its machine until the next machine is free. The objective of this study is to find a sequence that independently minimizes the maximum and the Total completion time criteria. We propose an Artificial Bee Colony algorithm to solve iteratively the blocking problem under three basic steps. These steps are efficiently designed. We talk about initialization, position updating and termination. We use discrete operators to transform elite solutions to other ones for every group of bees: employed, onlookers and scout. The performance of the proposed algorithm is evaluated on the well-known benchmark sets of Taillard. Computational tests show that the algorithm is very efficient and promising with comparison to state-of-the-art algorithms. We report new best known solutions for the benchmark sets.

4 - A Genetic Algorithm for the Network Flow Problems with Non-linear Objective Functions.
Kiseok Sung

We present a Genetic Algorithm for the optimization of the network flow problems with non-linear objective functions. Though the network flow problems with linear objective functions are easy to solve with the solution methods of linear programming, those with non-linear objective functions are not so easy and we can solve those problems with the metaheuristics such as Genetic Algorithm. To apply the Genetic Algorithm efficiently, the characteristics of the problem are investigated. The network flow problems have flow conservation equations, those should be satisfied by the solutions. It is not easy to satisfy these equality constraints during the evolution process of Genetic Algorithm. The proposed Genetic Algorithm uses the real vectors as the chromosomes. It uses a specially designed technique to maintain the feasibility of chromosomes during the evolution process. The feasibility maintaining technique accounts for only the equality constraints of the network flow problems, after transforming or eliminating the inequality constraints of the problems. We will show the results of running the proposed Genetic Algorithm for some test problems. In the analysis of the speed of convergence and the quality of solution, several crossover and mutation operators are compared with each other.

■ MC-50
Monday, 12:30-14:00 - Graham Hills GH512, Level 5

Quay Crane Scheduling and Slot Planning

Stream: Container Terminals
Invited session
Chair: *Christian Bierwirth*

1 - A Decomposition Approach to Solve The Quay Crane Scheduling Problem
Afonso Sampaio, Sebastián Urrutia, Johan Oppen

In this work, we propose a decomposition approach to exactly solve the Quay Crane Scheduling Problem (QCSP). This is an important maritime transportation problem faced in container terminals where quay cranes are used to handle cargo. The objective is to determine a sequence of loading and unloading operations for each crane in order to minimize the completion time. We solve a MIP formulation for the QCSP decomposing it into a vehicle routing problem and a corresponding scheduling problem. The routing sub-problem is solved by minimizing the longest crane completion time without taking crane interference into account. This solution provides a lower bound for the makespan of the whole problem and is sent to the scheduling sub-problem, where a completion time for each task and the makespan are determined. This information is used to update the best solution found and to provide cuts to the routing problem. Cuts are used to avoid the generation of the same or similar routes that cannot further improve the best known solution. This scheme resembles Benders' decomposition and, in particular, the scheme underlying combinatorial Benders' cuts, but the cut generation we propose does not rely on finding an irreducible infeasible subsystem. Rather, the scheduling sub-problem is always feasible and we derive cuts from the scheduling solution. We evaluate the proposed approach by solving some instances and comparing the results with other methods available in the literature.

2 - A New Genetic Algorithm for Minimizing Makespan in Quay Crane Scheduling Problem
Yusuf Yılmaz, Osman Kulak, Mustafa Egemen Taner, Aybüke Alper

The scheduling of QCs is an important research topic related to berth operations, which determines to a large extent the efficiency of container terminals. In this paper, we propose a new GA methodology including unidirectional mutation operator for minimizing makespan in QC scheduling problem. Detailed numerical experiments are conducted to evaluate the performance of the proposed methodology. The numerical results show that the proposed methodology generates efficient solutions in terms of solution quality and CPU time in all of the benchmark instances.

3 - Quayside Operations Planning Under Uncertainty
Cagatay Iris, Jian Gang Jin, Der-Horng Lee

The quayside operation problem is one of the key components in the management system for a container terminal. This work focuses on three important problems that represent a bottleneck on terminal operations: Berth Allocation Problem (BAP), Quay Crane Assignment and Scheduling Problems (QCASP).The state-of-art models mostly rely on forecasted, deterministic vessel arrivals, and they mostly assume that uniform QC operations is maintained. However, in reality, these parameters are mostly random. In this study, we present a stochastic programming approach based on a decomposition algorithm to solve this problem under uncertainty. The preliminary results show that our approach efficiently solves the problem compared to deterministic equivalent formulation.

4 - GRASP for the Slot Planning Problem
Francisco Parreño, Ramon Alvarez-Valdes, Dario Pacino

We address the slot planning phase, in which the containers assigned to a container ship location have to be stowed, satisfying many conditions related to the way in which containers have to be stacked, the weight distribution and the specific conditions regulating the containers with dangerous products. The main objective is to pack as many containers as possible, all the assigned containers if they fit into the location, and the secondary objective is to minimize the number of unproductive moves of containers that have to be removed just to get access to other containers below them. Apart from that other objectives are considered.

In order to study the structure of the problem, we have developed an integer linear model. With the purpose of solving in an efficient way problems of realistic size, we have developed a GRASP algorithm, including two constructive methods, several randomization strategies, and two improvement moves. The algorithms have been tested on a set of real-world instances. The results show that the GRASP algorithm outperforms recently reported algorithms and can easily accommodate other additional constraints.

■ MC-51
Monday, 12:30-14:00 - Graham Hills GH542, Level 5

Transportation Management

Stream: Traffic and Transportation
Invited session
Chair: *Xavier Cabezas*

1 - Curve estimation of rail based passenger transportation in Turkey
Kadir Berkhan Akalın, Murat Karacasu, Arzu Altın Yavuz, Barış Ergül

Railways are enjoying a period of significant in Turkey with major investment in high-speed lines to freight and passenger transportation in major cities across the country. The main aim of this paper is to modeling the level of rail based passenger transportation in Turkey. Curve estimation passenger demand model is using annual data of passenger transportation from 1977 to 2013. Some estimated models was used to model the rail based passenger transportation data from 1977 to 2013. Cubic estimation model showed that number of rail based passenger in Turkey would continue to increase.

2 - The departure-time choice equilibrium of the corridor problem with discrete multiple bottlenecks: modeling, solvability, and uniqueness
Shunsuke Hayashi, Takashi Akamatsu, Kentaro Wada

In this study, we provide a transparent approach to the analysis of dynamic user equilibrium and clarifies the properties of a departure-time choice equilibrium of a corridor problem involving discrete multiple bottlenecks. We reformulate the equilibrium problem as the linear/nonlinear complementarity problems by using the Lagrangian-like coordinate system instead of the existing Eulerian coordinate system. Then we analyze the existence and uniqueness of the equilibria. We also report some numerical observations.

3 - Pedestrian Road Safety Management
Aleksandra Romanowska, Kazimierz Jamroz, Lucyna Guminska

Poland is the EU's most dangerous and least friendly country for pedestrians. Pedestrian accidents are usually complex and the result of many factors involving road user behaviour, road design, roadside and the vehicle. The majority of pedestrian accidents in Poland are caused by drivers and pedestrians in areas of conflict, poor road planning and design, badly maintained road infrastructure and pedestrian protection equipment and a lack of good and systemic legislative and organisational solutions. To ensure that pedestrian safety measures and schemes are optimal and effective, we need extensive knowledge on the workings of the man-vehicle-road system including pedestrians as road users. The paper gives a characteristics of Poland's pedestrian safety compared to other countries and points out the seriousness of the problem. It presents methods for identifying risks to help with a clear determination of the most hazardous sites on our roads and the most critical problems to be solved. Next, a set of tools are presented for managing pedestrian road safety. Pedestrian road safety management involves a formalised and repetitive procedure which brings together risk assessment and risk response as it occurs on the road network. The risk-based approach is used for pedestrian safety management. Three types of management are distinguished: strategic, tactical and operational. The risk management method used here includes the phases of risk assessment and risk response. The object

4 - An ILP-based approach for the synchronization of traffic lights problem on networks.
Xavier Cabezas, Sergio García Quiles

The synchronization of traffic light problem (STLP) on a transportation network has been a topic of interest since traffic lights have been in our lives. Finding a faster method for solving the STLP represents a challenge even today with the most advanced computer technology. In this work, we present an ILP-based solution procedure that adapts an existing methodology which uses an iterative network decomposition method that divides the problem into subproblems that can be solved more easily in order to obtain a feasible solution for the original problem. A greedy decision procedure is used in each iteration. The proposed method uses a tabu search scheme in the subproblem stage. The method has been tested on random grid graphs for the symmetric case of STLP and computational results are shown.

■ MC-52
Monday, 12:30-14:00 - Graham Hills GH554, Level 5

Financial Mathematics 3

Stream: Financial Mathematics and OR
Invited session
Chair: *Aiko Kurushima*

1 - Heston-Type Stochastic Volatility with a Markov Switching Regime
Katsumasa Nishide

Several empirical papers have documented that the slope of volatility smile/skew is largely independent of the current level of volatility in financial markets, implying that single factor stochastic volatility models may be limited in their ability to capture the dynamic nature of the volatility surface. To reflect the properties observed in actual markets, we develop a Markov switching version of the original Heston's stochastic volatility model where the long-run mean volatility is

allowed to switch between regimes to price a plain-vanilla stock option under the setting. A semi-analytic formula is obtained and numerically calculated. The formula contains solutions of matrix ODEs, whose order is equal to the number of regimes. The methodologies are followed by Elliott and Osakwe (2006) and Elliott and Nishide (2014). More concretely, we firstly derive a characteristic function of the log stock price from a similar discussion to Elliott and Nishide (2014) and then calculate its option price with the Fourier inversion technique used in Elliott and Osakwe (2006). Our model is advantageous in the following sense. First, our model is flexible enough to produce a wide variety of volatility surfaces by properly setting the number of regimes and parameter values. Second, our price formula is semi-analytical and so our model in fact retains mathematical tractability.

2 - New Monte Carlo simulation based on Multilevel Monte Carlo method for American style option
Hitoshi Inui, Katsunori Ano

Multilevel Monte Carlo(MLMC) method was proposed in Giles(2008). From the view point of variance reduction, it has been reported that MLMC performance is superior to the performance of the standard Monte Carlo(SMC) method. In this talk, we propose a new Monte Carlo method which is based on Giles's MLMC. We use the three methods, i.e. our method, MLMC and SMC, to price American style option(e.g. Game option(Kifer(2000)), plain American option). We analyze the pricing results of the three methods.

3 - Multilevel Monte Carlo simulation for American option on jump diffusion process
Kengo Sumimoto, Katsunori Ano

We would like to consider and test how the Multilevel Monte Carlo (MLMC) method is good for the derivative evaluations. In this paper, we examine the improvement of performance for the price of American put option by Multilevel Monte Carlo Method on jump diffusion process.

■ MC-53
Monday, 12:30-14:00 - Graham Hills GH614, Level 6

Dynamic Programming and its Applications 2

Stream: Dynamical Systems and Mathematical Modelling in OR
Invited session
Chair: *Yukihiro Maruyama*
Chair: *Seiichi Iwamoto*

1 - Three Dualizations
Yutaka Kimura, Takayuki Ueno, Seiichi Iwamoto

We take a primal minimization problem without constraint and its dual problem. In this talk, we discuss how to derive the dual problem from the primal one. Thus, we present three derivation methods — (1) dynamic, (2) plus-minus and (3) inequality —. The dynamic method is an expansion of the Lagrangian method for constraint optimization. The plus-minus method is based upon Fenchel duality. The inequality method is based upon the Arithmetic-mean/ Geometric-mean inequality.

2 - Seven Duals – quadratic optimization –
Takayuki Ueno, Yutaka Kimura, Seiichi Iwamoto

We consider a minimization problem of sum of three squares as a primal problem. In this talk, we show that the primal problem as a whole corresponds to seven dual (maximization) problems. We derive each of dual problems from the primal problem. By solving an equality condition, we give the optimal solution for both problems. In addition, we explain an equality condition and the optimal solution for minimization of a square and minimization of sum of two squares as this subproblem.

3 - A green supply chain model considering classification by quality levels
Hitoshi Hohjo

This research investigates a green supply chain where a retailer collects used products from customers with an incentive payment. A part of collected products is reproduced by a manufacturer which may cause a defect in the reproduction process. This system has reproduced products by using recyclable parts with acceptable quality levels, sold products which are classified into low-level to be reproduced, and disposal products. The product demand is given by the known distribution. We formulates it as a mathematical model and determines the optimal collection incentive of used products and two classified quality levels under the maximization of the expected profits.

4 - Super-Strong representation theorems for non-deterministic sequential decision processes
Yukihiro Maruyama

This paper studies the relation between a given non-deterministic discrete decision process (nd-ddp) and subclasses of non-deterministic sequential decision process (nd-sdp) which is a finite non-deterministic automaton with a cost function. We show super-strong representation theorems for the subclasses of non-deterministic monotone sequential decision process (nd-msdp), for which the functional equations of non-deterministic dynamic programming are obtainable. The super-strong representation theorem provides a necessary and sufficient condition for the existence of the subclass of nd-msdp with the same set of feasible policies and the same cost value for every feasible policy as the given process nd-ddp.

■ MC-54
Monday, 12:30-14:00 - Graham Hills GH617, Level 6

Recent Advances in Dynamics of Variational Inequalities and Equilibrum Problems 1

Stream: Recent Advances in Dynamics of Variational Inequalities and Equilibrum Problems
Invited session
Chair: *Patrizia Daniele*

1 - Stability of Tatonnement Dynamics in Achieving Economic Equilibrium
Terry Rockafellar

In classical models of economic equilibrium, in which market prices are able to balance the supply and demand among agents, there is a long-held belief that equilibrium is generally unstable. In particular, the tatonnement process that has been proposed as a way for prices to adjust, can fail to converge. However, attention has not been paid to having the process start close enough to an equilibrium, not only in prices but also in holdings. When closeness in that sense is taken into account, the surprising news is that the dynamics are sure converge under relatively ordinary assumptions.

2 - Evolutionary Variational Inequalities and Coalitional Games in Sustainable Supply Chain Networks
Laura Rosa Maria Scrimali

In this paper an equilibrium model of a sustainable supply chain coalitional game is developed. The supply chain network structure consists of three layers of decision-makers (providers, manufacturers and retailers) in a duopolistic market, in the case when prices and shipments evolve in time. Equilibrium conditions corresponding to a Cournot-Nash equilibrium are derived and an evolutionary variational inequality formulation of the coalitional game is established. The existence of solutions is discussed and a numerical example is given.

3 - An Optimization Model for Business Management
Patrizia Daniele, Gabriella Colajanni

We present a supply chain network model with four different tiers of decision makers (suppliers of raw materials, manufacturers, retailers, demand markets), and we derive the optimality conditions and the associated variational inequality problem for the representatives of each

level and for the total supernetwork. Then, to the forward chain we add a reverse chain model where manufacturers, using the unsold product given back from retailers, after reworking, produce a new commodity which will be sold to new retailers. Also in this case we study the behavior of manufacturers obtaining their optimality conditions and the governing variational formulation. Finally, we apply our network model to a well-known agribusiness company (Valle del Dittaino, Italy).

■ MC-55
Monday, 12:30-14:00 - Graham Hills GH626, Level 6

Long Term Financial Decisions

Stream: Long Term Financial Decisions
Invited session
Chair: *Thomas Burkhardt*
Chair: *Ursula Walther*

1 - How SMEs select financing instruments — a survey among bank advisers
Ursula Walther, Marco Goeck

Selection of financing instruments is driven by factors as manifold as the instruments' characteristics. Besides capital structure firms care for costs, flexibility, stability, tax effects, independence and many other features. To gain a better understanding in which way companies decide, many studies have questioned the firms directly. We contribute to the literature by exploring these factors from a new perspective, the bank advisers, who form a well-informed but outside group. In a survey the advisers of a large German bank reported about their perception of clients' decisions. Evaluation shows only moderate support for classic capital structure theories. In contrast, pragmatic considerations, the specific situation of the company and the personality of the decision maker appear to be relevant. In addition, as advisers are specialized, we are able to distinguish our results by company size to obtain a differentiated view.

2 - Timing Success Explained — The Fallacy of Beating Efficient Markets
Peter Scholz, Ursula Walther

According to the efficient market hypothesis (EFM), technical trading rules should not have prediction power. However, a significant number of academic studies confirm at least slight excess returns. By applying parametric and historical simulation techniques, we show the connection between timing success and statistical properties of the underlying. Therefore, we check the time series data of prior studies with respect to their statistical properties in order to explain their findings. As long as drift, volatility and autocorrelation of a time series are unpredictable, there seems to be no benefit from technical trading rules.

3 - Leverage Ratio: One Size Does Not Fit All
David Großmann

How should capital requirements be calibrated to consider the particularities of different bank business models? The goal of the research project is to develop unequal leverage ratios which are tailored to the respective bank business models for both listed and unlisted banks in Europe. The utilized model relies on the capital structure theories of Modigliani/Miller. Their theory for the determination of the optimal capital structure will not be used to increase bank's value, but to focus on the cost of regulatory capital. Therefore, the WACC-model will be developed into the "Weighted Average Cost of Regulatory Capital' (WACRC). A capital structure is optimal at the point of the lowest WACRC. The model will be empirically tested on the basis of real financial figures of 150 banks in Germany and Europe. Due to individual risks (and costs) different bank business models are considered to have diverse optimal WACRC's. For that reason a "one size'-leverage ratio does not fit all.

4 - An Analytical Approximation for the Pricing of VWAP Options

Masaaki Kijima

This paper proposes a unified approximation method for various options whose payoffs depend on the volume weighted average price (VWAP). Despite their popularity in practice, quite few pricing models have been developed in the literature. Also, in the previous works, the underlying asset process is restricted to the geometric Brownian motion. In contrast, our method is applicable to the general class of continuous Markov processes such as local volatility models, stochastic volatility models, and their combinations. Moreover, our method can be used for any type of VWAP options including Asian and Australian options with fixed-strike, floating-strike, continuously sampled, discretely sampled, forward starting, and in-progress transactions. (joint work with H. Funahashi)

■ MC-60

Monday, 12:30-14:00 - Graham Hills GH813, Level 8

Integrated Logistics

Stream: Routing I - Models and Methods
Invited session
Chair: *Luca Bertazzi*
Chair: *Pantelis Lappas*

1 - Simultaneously Handling Routing And Scheduling Through a GRASPxELS Algorithm

Marina Vinot, Philippe Lacomme, Aziz Moukrim, Alain Quilliot, Daniele Vigo

Production and transportation scheduling problems (PTSP) are particularly important in world with an increasing global competition. The problem which we study here was first addressed by Geismar and al. in 2008 and involves a single-machine-single-vehicle integrated production and transportation of short lifespan products. More precisely, we have a machine M, a vehicle V with capacity Q, together with customers each requiring the delivery of q(i) units of a given product. In addition products must be delivered to customers within a time which does not exceed some lifespan value B. The goal is to simultaneously schedule production and transportation by minimizing the overall makespan. We adopt a GRASPxELS approach to define the sequences which adopts an alternative way of constructing sequences of operations as collections of feasible tours, while implementing a 2-label Split process which allows taking into account the lifespan constraint in a more flexible way. Also, we test the impact of relaxing the no-wait restriction while solving the 2-machine flow shop The GRASPxELS algorithm introduces a control on the local search loop which consists into compromising between respective production and routing criteria. We test our algorithm on Geismar and al. instances as well as on more general instances.

2 - Impact of Postponement and Sectorisation Strategies in Inventory Routing Problems

Gu Pang, Luc Muyldermans, Supanan Phantratanamongkol

We study the impact of postponement and sectorisation strategies on Inventory Routing Problems. Our aim is to find the optimal accumulation time that results in the optimal trade-off between routing and inventory holding costs. The problem instances are generated and solved by a Continuous Approximation approach. These extensive computational experiments explore the impact of both strategies on the total inventory routing cost. The results report that the optimal accumulation time is dependent on the parameters, including the sub-service regions (i.e. longer postponement horizon or less frequent deliveries for clients located further away from the depot), client demand rates (i.e. shorter accumulation time or JIT distributions for clients with smaller, or less bulky demands), and client densities (i.e. shorter accumulation time or more frequent deliveries for the sub-service regions with high client densities). Furthermore, the use of both postponement and sectorisation strategies help reduce total costs given the fact that certain trade-offs need to be considered since the benefit of total cost reduction is less substantial when items become bulkier, as well as when inventory holding cost dominates routing cost.

3 - A Genetic Algorithm for the Inventory Routing Problem with Time Windows

Pantelis Lappas, Manolis Kritikos, George Ioannou

A typical Inventory Routing Problem (IRP) can be described as the combination of vehicle routing and inventory management problems, in which a supplier coordinates the replenishment process of a number of geographically dispersed customers. This is the case of Vendor Managed Inventory (VMI) systems where the supplier has to make three simultaneous decisions for a given planning horizon: (1) when to visit its customers, (2) how much to deliver to each of them when they are served, and (3) how to combine customers into vehicle routes. The Inventory Routing Problem with Time Windows (IRPTW), which is not addressed in the literature so far, is a generalization of the standard IRP involving the added complexity that every customer should be served within a given time window. Due to the NP-hard nature of the IRPTW, it is very difficult to develop an exact algorithm that can solve large scale problems in a reasonable computation time. As an alternative, we present a Genetic Algorithm (GA) to handle the IRPTW. Both the formulation of IRPTW and implementation of GA by a numerical example will be discussed.

4 - An Inventory Routing Problem with Stochastic Travel Times

Xiaolan Chen, Luca Bertazzi, Riccardo Mogre

We study an inventory routing problem in which only one supplier and one customer are involved. Travel times between these two nodes are stochastic and gradually revealed over time, and a fixed transportation cost occurs for each trip. We aim at minimising the expected sum of vehicle operating, inventory holding and out-of-stock penalty costs over a planning horizon. First, we formulate and solve a deterministic-travel-time version of this problem using mixed-integer programming. Then, we formulate a stochastic-travel-time version using dynamic programming. A heuristic solution is proposed for the latter formulation by integrating a rollout algorithm and the optimal solution of mixed-integer programming models. We complement the analytical results with computational experiments, and managerial insights are provided concerning uncertainties in travel times.

■ MC-61

Monday, 12:30-14:00 - Graham Hills GH816, Level 8

Dynamic Programming 3

Stream: Dynamic Programming
Invited session
Chair: *Lidija Zadnik Stirn*

1 - Production control policies for flexible manufacturing systems

Christopher Kirkbride

We consider the problem of determining (close to) optimal production policies in a flexible manufacturing system where each factory has the capability to produce more than one product. We have developed two heuristic approaches based upon stochastic dynamic programming to solve this challenging problem: i) A decomposition-based dynamic programming index heuristic; and ii) a parametric approximation to the optimal value functions estimated by rolling regression. The strong performance of these heuristics has been shown in comparison to optimal in small scale problems and against competing heuristics in large scale problems.

2 - Robust optimisation models and meta-heuristics for dynamic scheduling in manufacturing systems

Mohanad AL-Behadili, Djamila Ouelhadj, Dylan Jones

In this paper, a robust optimisation model for the dynamic permutation flow shop scheduling problem is proposed and examined. The optimisation model considers utility, stability and robustness measures to minimize the effect of different real-time events on the planned schedule. The proposed solution method is a predictive-reactive approach that uses particle swarm optimisation (PSO) and Iterated Greedy (IG) to generate robust schedules in the presence of real-time events. The robust optimization model, PSO and IG algorithms have been evaluated under different types of disruptions including machine breakdown and new job arrival. The results have shown that using the proposed

robust optimisation model gives better results than using only the utility objective, due to the objective function of the proposed model that aims to minimize utility, instability and robustness simultaneously.

3 - Establishing the most efficient environmental unit by DEA, group AHP and DP: a case of public forest service entities in SLO

Lidija Zadnik Stirn, Vasja Leban, Petra Groselj, Špela Pezdevsek Malovrh, Janez Krč

Evaluating the efficiency of managing the environment is a multi-phase, multi-criteria and group decision problem. It is not merely valued by economic value since the environment provides also other key services, such as being hotspot of biodiversity, tourism, recreation, water supply, as well as supporting the livelihoods of owners, local people and the society as the whole. To consider ex-post and ex-ante activities regarding the environment a dynamic model based on DEA, group AHP and Bellman's principle of optimality was generated. The experts covering topics in management, protection of the environment and socio-economic perspectives are included in the decision process. In the model the stages are addressed as years, the states by a combination of variables inventorying the environmental situation, decisions are management for economic, ecological or social outputs, while the returns are weighted outcomes of DEA (technical effects) and group AHP (social, ecological effects). The deterministic effects are identified as DEA/MI, where the MI (Malmquist Index) measures the improvement or decrease in efficiency of environmental unit over a period of time. The risk, subjectivity and lack of information are captured by aggregation of individual comparison matrices into a joint interval matrix. Presented participatory and dynamic model is illustrated at public forest service units which were investigated within the COOL project (Wood/Wisdom ERA-net).

■ MC-62

Monday, 12:30-14:00 - Livingstone LT203, Level 2

Operations Research 3

Stream: Operations Research, other
Contributed session
Chair: *Rui Oliveira*

1 - Modelling the Strategic Adoption of Open Innovation for Improved Decision-Making
Stuart MacKinven

In order for the field of open innovation to develop there is a need for other academic domains to contribute knowledge. Therefore, this paper considers the applicability of OR in open innovation. If firms are to benefit from open innovation, it is necessary to be aware of how they can support open innovation inside their organisation. This paper aims to show how modelling open innovation through its various constructs can assist decision-makers. The model illustrated in this paper was developed as an output from a deductive based research process. A literature review of innovation, strategy, and business process literature provided the necessary knowledge upon which to articulate how open innovation may be strategically implemented. Based on empirical data collected from a wider research project that aimed to understand how firms engage in open innovation, it was found that they do not necessarily implement open innovation as depicted in the model. Instead, firms are typically involved in various forms partnering or joint venture activity. However, as firms are interested in understanding more about open innovation implementation, the model provides a theoretical proposition and structure upon which to base future decisions, as well as providing a mechanism for decision-makers to target areas in the system that may be causing problems once open innovation has been introduced in an organisation. To date, the use of OR has been overlooked by the open innovation community.

2 - A New License for Open Source 3D Printing
Su Jung Jee, Bokyeong Lee, So Young Sohn

Existing open source license systems are limited to adequately protect both software and hardware of 3D printing. This paper suggests an appropriate license for open source 3D printing via choice based conjoint (CBC) analysis reflecting the opinion of different participants: "The users' who just use the open source design file; and "The developers' who not only use but also develop the open source design file.

Through the CBC analysis, we test whether the users prefer the weakly restrictive license while the developers prefer the strongly restrictive license. The empirical results indicated that both groups tend to prefer the weakly restrictive license and whether to allow the commercial use of a printed object based on an open design file is the most influential factor on the license design. This study contributes to minimizing future legal conflicts in 3D printing licensing and establishing successful 3D printing ecosystem.

3 - Territorial Analysis of Education Facilities Networks: a Great Lisbon Case-Study
Rui Oliveira, Marisa Pedro

Education is crucial for Society's development, where school facilities are singular spaces for the educational practice. In the last decade, Portugal has been facing increasing geographic discrepancies between the educational facilities capacity and education demand. Namely, in the largest urban areas, such as the Great Lisbon, population dynamics created unbalanced situations, with overcrowded schools where the number of students exceeds the capacity for which the infrastructures were originally planned. In this paper, we present a prospective analysis framework for assessing the adequacy of the secondary schools network to current and future demand evolution taking into account the population dynamics in the Great Lisbon Region. This includes education demand forecasting based on demographic projection models, coupled with strategic options derived from education policies, leading to a geographic-based education services demand-supply balancing analysis.

4 - Using recent developments to explain nonparametric cost inefficiency: the case of primary aluminum industry
Nadia Kpondjo, Frederic Lantz

In this paper we use recent developments in nonparametric DEA models to measure technical and allocative efficiency in the world primary aluminum smelters and to analyse the impact of environmental factors on the attainable set and/or on the distribution of these efficiencies. We build two DEA models: a production frontier and a cost frontier. We use a cross section data set for this industry over three periods 2005, 2009, 2012. We assess the disparity effects of ownership, location and integrated plants on conditional efficiency. Moreover, we point out significant differences between these disparity effects over the recent years.

■ MC-66

Monday, 12:30-14:00 - Livingstone LT209, Level 2

Convexity and applications 2

Stream: Optimization
Invited session
Chair: *Francisco Javier Aragón Artacho*

1 - A Lagrangian Relaxation Algorithm for Modularity Maximization
Yoichi Izunaga, Kotohumi Inaba, Yoshitsugu Yamamoto

The modularity proposed by Newman and Girvan is one of the most common measures when the nodes of a graph are grouped into communities consisting of tightly connected nodes. Due to the NP-hardness of the problem, few exact algorithms have been proposed. Aloise et al. formulated the problem as a set partitioning problem, which has to take into account all, exponentially many, nonempty subsets of the node set, and makes it difficult to secure the computational resource when the number of nodes is large. Their algorithm is based on the linear programming relaxation and uses the column generation technique. Although it provides a tight upper bound of the optimal value, it can suffer a high degeneracy due to the set partitioning constraints. In this study, we propose an algorithm based on the Lagrangian relaxation. We relax the set partitioning constraints and add them to the objective function as a penalty with Lagrangian multipliers, and obtain the Lagrangian relaxation problem with only the binary variable constraints. For a given Lagrangian multiplier vector, an optimal solution of the Lagrangian relaxation problem can be obtained by checking the sign of coefficients, but it is hard to compute all the coefficients of variables. Then we apply the column generation technique in order to alleviate the computational burden. Moreover, we develop an efficient bounding method on the optimal modularity.

2 - New glimpses on duality for evenly convex functions
José Vicente-Pérez

In this talk we present a new exact conjugation scheme for the class of extended real-valued evenly convex functions defined on general topological vector spaces which is obtained by exploiting the relationship between even convexity and even quasiconvexity. We also show a new characterization of the even convexity of a function at a given point, and establish the links between even convexity and subdifferentiability and the regularization of a given function. Finally, we derive a sufficient condition for strong duality fulfillment in convex optimization programs.

3 - Douglas-Rachford feasibility methods for matrix completion problems
Francisco Javier Aragón Artacho

Many successful non-convex applications of the Douglas-Rachford method can be viewed as the reconstruction of a matrix, with known properties, from a subset of its entries. In this talk we discuss recent successful applications of the method to a variety of (real) matrix reconstruction problems, both convex and non-convex.

■ MC-67

Monday, 12:30-14:00 - Livingstone LT210, Level 2

Topics in Combinatorial Optimization I

Stream: Combinatorial Optimization
Invited session
Chair: *Silvano Martello*
Chair: *Paolo Toth*

1 - A Unified Exact Approach for Knapsack Problems with Side Constraints
Rosario Scatamacchia, Federico Della Croce, Fabio Salassa

We propose a unified exact approach for two different generalizations of the 0-1 Knapsack problem, that is the 0-1 Knapsack Problem with Setups and the 0-1 Collapsing Knapsack Problem. In the first problem, the items belong to disjoint families (or classes) and they can be picked only if the corresponding family is activated. The selection of a class involves setup costs and resource consumptions thus affecting both the objective function and the capacity constraint. In the 0-1 Collapsing Knapsack Problem the capacity of the knapsack is not a scalar but a non-increasing function of the number of items included, namely it is inversely related to the number of items placed inside the knapsack. The unified approach involves three main steps and relies on an effective exploration of a specific set of variables that leads to solve standard knapsack problems. It proves to be very effective both on the 0-1 Knapsack Problem with Setups and on the 0-1 Collapsing Knapsack Problem and is capable of solving to optimality large size instances with limited computational effort. The method significantly outperforms the state of art solver CPLEX 12.5 and compares favorably to the algorithms available in literature.

2 - Controlling Uncertainty and Variability in MILP Models
Carlo Filippi, Wlodzimierz Ogryczak, M. Grazia Speranza

The maximin/minimax models are traditionally used to protect the decision maker against risk intended as the worst possible outcome. Such models are very conservative and may cause a relevant worsening of the overall objective function. On the other hand, decision models based on the maximization/minimization of the average outcome may overlook very bad situations that may happen. In many applications, the outcome is determined by the realization of an uncertain event (e.g., future price). However, there are completely deterministic models where outcomes correspond to different performance measures. In location problems, the distance of clients of a system to a nearest facility form a distribution of outcomes; this applies also to various systems serving many users. Moreover, in many dynamic optimization problems a distribution of uniform individual objectives may be associated with a similar event in various periods.

The goal of this work is to extend the maximin/minimax criteria to maximin(p)/minimax(p) criteria that depend on a parameter p representing the percentage of worst outcomes against which the decision

maker aims at being protected. The criteria are strictly related to the maximization of the worst conditional expectation. We analyse the extended criteria, discuss how to embed such criteria in general MILP models, and we show the effectiveness of the proposed criteria applying them to classic combinatorial optimization problems.

3 - Adaptivity in Variants of the Stochastic Knapsack Problem
Aleksander Vainer, Asaf Levin

We consider stochastic variants of the NP-hard 0/1 knapsack problem in which item values are deterministic and item sizes are independent random variables with known, arbitrary distributions. Items are placed in the knapsack sequentially, and the act of placing an item in the knapsack instantiates its size. The goal is to compute a policy for insertion of the items that maximizes the expected total value of items placed in the knapsack. These variants that we study differ only in the formula for computing the total value of the final solution obtained by the policy. We consider both non-adaptive policies (that designate a priori a fixed subset or permutation of items to insert) and adaptive policies (that can make dynamic decisions based on the instantiated sizes of the items placed in the knapsack thus far). Our work characterizes the benefit of adaptivity. For this purpose we use a measure called the adaptivity gap: the supremum over instances of the ratio between the expected value obtained by an optimal adaptive policy and the expected value obtained by an optimal non-adaptive policy. We show that for some variants this quantity is bounded by a constant while for others it is unbounded.

■ MC-69

Monday, 12:30-14:00 - Livingstone LT212, Level 2

Applications of Business Analytics

Stream: Business Analytics and Intelligent Optimization
Invited session
Chair: *Richard Weber*

1 - Visualizing Proximity in Graphs by (Piecewise) Rectangular Maps
Emilio Carrizosa, Vanesa Guerrero, Dolores Romero Morales

In this talk we address the problem of representing a set of individuals, to which there are attached weights and a binary relation, by means of a rectangular map, i.e., a subdivision of a rectangle into rectangular portions. It is assumed that each portion is associated with one individual, the areas of the portions reflect the weights, and portions adjacencies should reflect the adjacencies in the binary relation. This rectangles location problem is formulated as a three-objective Mixed Integer Nonlinear problem. The first objective seeks to maximize the number of true adjacencies that the rectangular map is able to reproduce, the second one is to minimize the number of fake adjacencies that the rectangular map adds, and the last one is to minimize the total deviation of the areas of the portions in the rectangular map from the weights. We study the tradeoff between the objectives by solving the problem with the weighted summation of the objectives. Our numerical results demonstrate that is is possible to provide a collection of rectangular maps with different tradeoffs between an accurate representation of the weights by areas versus an accurate representation of the relation by adjacencies. As a second step, we address the same problem in which pieces are not constrained to be rectangles, but instead they are connected rectangles.

2 - Demand forecasting based on deep learning and hybrid data mining models in retail industry
Luis Aburto

Deep learning has proved to be an effective method to solve classification problems with great complexity. The objective of this work is to apply this methodology to solve a demand forecast problem in the retail industry and compare it with hybrid data mining methods based on multilayer perceptron and Arima methods. The main idea is to use deep learning arquitecture for preprocessing time series in order to predict non linear effects inside demand time series. Using deep learning for demand forecasting in the retail industry allows finding complex pattern regarding demand in the respective supply chains. It enables

us e.g. to identify stores within a particular supply chain that anticipate demand changes, to explain product substitution, to detect local effects of price and promotion elasticity, among others. We will show the case of a retail chain where deep learning improved the forecasting accuracy and identified a particular product category with seasonal and promotions effects.

3 - Hidden Markov models to understand crime pattern
Richard Weber, Paz Obrecht

Hidden Markov models (HMM) have been used for many different purposes, such as e.g. to explain the shopping behavior in retail stores. Applications of HMM have in common that the development of hidden (or latent) variables that are not visible to an observer can be explained by the development of observable variables. In order to better understand criminal behavior in public places we present a HMM where the observable variable "number of reported offenses' at a certain hot spot is used to estimate the latent variable "attractiveness' of that spot for criminals. Additional observable variables that could improve our model are e.g. illumination or police patrol. We show experiments based on real data we gathered in down town Santiago, the capital of Chile. Using this data we calibrated an agent-based simulation tool in order to generate data to test our proposed models. The results show that a HMM could be a strong tool in order to better understand the complex relations between the different variables that finally explain why offenses occur in certain places.

4 - Clustering Categories in Support Vector Machines
Amaya Nogales-Gómez, Emilio Carrizosa, Dolores Romero Morales

Support Vector Machines (SVM) is the state-of-the-art in Supervised Classification. In this paper the Cluster Support Vector Machines (CLSVM) methodology is proposed with the aim to reduce the complexity of the SVM classifier in the presence of categorical features. The CLSVM methodology lets categories cluster around their peers and builds an SVM classifier using the clustered dataset. Four strategies for building the CLSVM classifier are presented based on solving: the original SVM formulation, a Quadratically Constrained Quadratic Programming formulation, and a Mixed Integer Quadratic Programming formulation as well as its continuous relaxation.

The computational study illustrates the performance of the CLSVM classifier using two clusters. In the tested datasets our methodology achieves comparable accuracy to that of the SVM with original data but with a dramatic decrease in complexity.

■ MC-70

Monday, 12:30-14:00 - Livingstone LT303, Level 3

Automatic Algorithm Configuration and Adaptation

Stream: Data Science for Optimisation
Invited session
Chair: *Kevin Tierney*

1 - Neighborhood synthesis from an ensemble of MIP and CP models
Gianpaolo Ghiani, Tommaso Adamo, Tobia Calogiuri, Antonio Grieco, Emanuela Guerriero, Emanuele Manni

In this talk we present a procedure that automatically synthetises a neighborhood from an ensemble of Mixed Integer Programming (MIP) and/or Constraint Programming (CP) models. We move on from a recent paper by Ghiani et al in which a neighborhood structure is automatically designed from a (single) MIP model through a three-step approach: 1) a semantic feature extraction from the MIP model; 2) the derivation of neighborhood design mechanisms based on these features; 3) the search of a "proper mix" of such mechanisms in an automatic configuration phase. Here, we extend the previous work in order to generate a suitable neighborhood from an ensemble of MIP and/or CP models of a given combinatorial optimization problem. Computational results show relevant improvements over the previous approach.

2 - Self-generating and co-evolutionary memetic algorithms
Seán McGarraghy, James McDermott, Allen Butler, Louis Smith

We investigate the performance of the memetic algorithm (MA) metaheuristic on the price-based unit commitment problem (PBUC), of particular relevance to deregulated energy markets. MAs combine some form of evolutionary algorithm (EA) with a local search. The important aspect which sets co-evolving MAs apart from a simple hybrid approach is that there are two populations - the base EA population and the memes, representing local search - the parameters of which are free to evolve either separately or linked to the individuals from the EA. Previously, MAs were tested against UC but these lacked some key features of memes and memetic evolution which we employ.

We apply a third-generation self-adapting MA (combining multi-meme and hyperheuristic approaches) to the PBUC problem, using rules similar to that applied to NK landscapes (Krasnogor & Gustafson, 2004): specifying a) how many bits of the chromosome to search at once and b) whether to search among adjacent bits or random neighbours. We adapt this to better suit the PBUC problem, leading to a simpler meme structure, where the meme specifies only the length of the search template and search is performed only on contiguous bits.

The self-generating MA was found to converge rapidly for 4x8, 10x24 and 60x24 test cases, requiring 50-75 iterations to achieve a 100% success rate for the 4- 10- and 60-unit test cases. Our self-adapting approach found higher quality solutions than in other work reported to date on this problem.

3 - Evaluation and optimization of metaheuristic algorithms for the vehicle routing problem with time windows
Jeroen Corstjens, An Caris, Benoît Depaire

The vehicle routing problem with time windows (VRPTW) is an extension to the traditional vehicle routing problem. Finding an optimal solution for the NP-hard VRPTW is difficult. Therefore, a large number of heuristic procedures have been proposed for VRP problems.

There is, however, no agreed-upon methodology used for comparing heuristic performance on these problems. In VRP literature, heuristic performance is traditionally studied by evaluating the performance of a specific heuristic on a set of standard test problems, but any conclusions made are limited to the benchmark set and often not robust. To obtain statistical meaningful conclusions experimental design should be applied on the different levels of the various algorithmic parameters and the results compared by appropriate techniques. This need for more scientific rigour in the operations research and heuristics community was already called for many years ago by several researchers. Nonetheless, few papers have made notion of using either design of experiment techniques or statistical tools for exploring data and testing hypotheses. In other research fields these are prerequisites for performing scientific work. Current VRP research can therefore make a significant methodological progress by applying a statistical approach to obtain a more rigorous evaluation and gain a more complete insight in and understanding of the different results. This research aims at developing such a methodological framework.

■ MC-71

Monday, 12:30-14:00 - Livingstone LT307, Level 3

Pricing & Revenue Management

Stream: Revenue Management
Invited session
Chair: *Olaf Menkens*
Chair: *Darius Walczak*

1 - When Does Better Quality Imply Higher Price?
Régis Chenavaz

This article analyses the conditions under which better quality implies higher or lower price. In an optimal control framework, I assume the following: The firm sets the dynamic pricing and product innovation policies. Product innovation raises quality, which drives production cost. Consumers are sensitive to price and quality. I derive a general

rule of price-quality relationship, which stresses the influence of quality on price through the effects of cost (positive), sales (negative), and markup (positive). This paper shows that the firm, while maximising the profit, may decrease the price despite quality and cost increase, because of the sales effect. The sales effect solves the puzzle of a negative price-quality relationship. More generally, the sales effect mitigates the ability for price to convey information about quality.

2 - Dynamic Pricing with a Worst Case Scenario Approach
Olaf Menkens

We consider the dynamic pricing problem as introduced by Gallego and van Ryzin (1994) assuming that the inventory or capacity level is uncertain within certain bounds. For instance, we think of retailers selling fashion which might get stolen or have insufficient quality. Another example are advertising slots in the broadcasting industry with their so—called make—good times. A worst case scenario ansatz, going back to Korn and Wilmott (2002) (developed in the context of portfolio optimization) will be used to solve this optimization problem. The problem is solved for exponential demand function (as in Gallego and van Ryzin (1994)) form and for demand functions with constant elasticity (introduced by McAfee and te Velde (2008)).

3 - Computing Higher Order Metrics in the Dynamic Revenue Management Models
Darius Walczak, David McCaffrey

Higher order metrics such as variance and other distributional moments are important in modeling risk in optimization problems. They are also more challenging computationally than linear load metrics such as load factor. We adopt an approach found in the Markov Decision Process literature to calculate variance of revenue under dynamic policies in single-resource revenue management or pricing problems. We show how it extends to other metrics that rely on the distribution of the revenue and how it can be applied in calculating efficient frontiers of interest. We compare computational advantages of the usual backward recursion vs. forward recursion, and discuss possible extensions to network problems.

■ MC-72

Monday, 12:30-14:00 - Livingstone LT311, Level 3

Discrete and Global Optimization 1

Stream: Discrete and Global Optimization
Invited session
Chair: *Gerhard-Wilhelm Weber*
Chair: *Emel Savku*

1 - Migrating Bird Optimization Approach for the Infrared Heating Problem in Thermoforming
Djamal Rebaine, Kahina Bachir Cherif, Fouad Erchiqui, Issouf Fofana

When heating a polymeric sheet by infrared radiation, the plastic sheet is transformed from glassy into rubbery state. This hot state combined with the gravity effect creates a non-uniform thickness distribution in the plastic sheet. A good modelling and optimization of the heating process can improve the uniform distribution of the heat in the formed thermoplastic sheet. A natural way to achieve this goal is to reduce the differences of energy absorbed by different areas of the thermoplastic sheet. The classical methods of optimization of thermoplastics radiation have been the subject of many studies in the literature in finding the optimum solution of continuous and differentiable functions. These methods are analytical and make use of the techniques of differential calculus in locating the optimum points. However, since some of the practical problems involve objective functions that are not continuous and/or differentiable, the classical optimization techniques have a limited scope in practical applications. Therefore, one way to circumvent this difficulty is to make the problem discrete so one can use iterative processes so as to produce solutions rapidly, but without the optimality guaranty. Within this approach, we first discretized the problem so as an optimization problem can be produced. The optimization problem we derived is to select a subset of n temperatures, among a given set of temperatures, so as to minimize the objective function.

2 - The Extremal Graphs for the Geometric-Arithmetic Index with Given Minimum Degree
Ljiljana Pavlovic, Tomica Divnic, Milica Milivojevic

The geometric-arithmetic index GA of a graph is defined as the sum of weights of all edges of graph. The weight of one edge is the quotient of the geometric and arithmetic mean of degrees of its end vertices. The predictive power of GA for physico-chemical properties is somewhat better than the predictive power of other connectivity indices. Let G(k,n) be the set of connected simple n-vertex graphs with minimum vertex degree k. We give a conjecture about the structure of extremal graphs of this index for n-vertex graphs with given minimum degree. For k greater or equal to q(n-1), where q is approximately 0.0874, we find extremal graphs in G(k,n) for which geometric-arithmetic index attains its minimum value or we give lower bound. When k or n are even, we show that the extremal graphs are regular graphs of degree k.

3 - A Chinese Postman Problem with Workload Balancing
Yasemin Limon, Meral Azizoglu

In this study, we consider a Chinese Postman Problem with multiple postmen. Each postman should start its tour at the depot and terminate at the depot. We aim to balance the workloads of the postmen by minimizing the sum of squared workloads. We formulate the problem as a pure integer nonlinear programming model. We find an efficient way of representing the subtours and eliminating them. We use these subtour elimination constraints in our branch and cut algorithm that detects the subtours and eliminates them once observed. Our experimental study with large-sized instances has revealed the satisfactory behavior of our branch and cut algorithm.

4 - Optimizing Performance Measures by Peer Selection Strategy in P2P Streaming Network
Yuliya Gaidamaka, Konstantin Samouylov, Sergey Shorgin, Ekaterina Medvedeva, Ivan Vasiliev

The rapid development of P2P streaming and the emergence of a variety of applications implementing this technology generate a lot of optimization problems for data delivery services. In the P2P streaming network, each user should select target users among its neighbors in order to download the data chunks. In this study, we investigate the influence of a neighbors' selection strategy to key indicators of quality of service in P2P streaming network. We formulate the optimization problem and introduce the mathematical model in terms of Markov chain, which takes into account transmission delays between server and peers (lags), chunks download strategy (including Rarest First, Latest First and Greedy strategies) and neighbors' selection strategy in the P2P network, to solve it. Strategies' selection affects such performance measures as the probability of playback continuity, the probability of startup latency, the probability of chunk availability, as well as the probability of collisions - the situation when a peer cannot download data from another peer because the latter does not have sufficient upload capability. On the basis of the mathematical model, we developed the software simulation tool for numerical analysis of neighbors' selection strategies by the criteria of maximization the probability of playback continuity and minimization the startup latency and present the result of the analysis.

■ MC-73

Monday, 12:30-14:00 - Collins CL205, Level 2

Forecasting with Neural Networks

Stream: Forecasting & Time Series Prediction
Invited session
Chair: *Sven F. Crone*

1 - The impact of coding seasonality and calendar effects on electricity load forecasting with neural networks
Fahad Al-Qahtani, Sven F. Crone

In the last decade, artificial neural networks (NN) have been applied successfully in daily load forecasting. While most research in this area has focused mainly on the design of the neural network model and the selection of input variables, determining the right way of coding seasonality and calendar effect into the model and examining their interactions with other input variables has not been investigated in detail. This includes the choice of coding used to represent the day of the

week, day of the year and holiday information. As a common practise, the majority of researchers try to deal with seasonality by segmenting the main time series into smaller subseries based on day type, season and holiday information. However this choice of segmentation is not usually based on empirical evaluation and does not provide a global model for all day types. To overcome this shortcoming, this paper investigates the influence of using different coding for seasonal variables in a systematic empirical evaluation where the impact of different coding choice is assessed on a real world data from the electricity market in the UK using a multifactorial analysis of variance. Our analysis provides empirical evidence that data coding choice has a significant impact on forecasting accuracy with certain schemes proving to be superior to others. There is also an indication of a direct impact between the selected schemes and the design of the NN model and the choice of other input variables.

2 - Forecasting crude oil prices by using a neural network model
Sevinç Güler Özçalik, Melih ÖzÇalik, Coşkun Bayrak

Forecasting and estimating the world crude oil prices is a dilemma, since that various unpredictable variables affect the trend. This paper proposed a multilayer feed-forward neural network analysis to forecast weekly crude oil spot prices. We used West Texas Intermediate (WTI) crude oil spot prices for testing target. The model involved five input parameters: crude oil consumption, production, crude oil and petroleum products, refiner net input of crude oil, and future contract prices. We applied the proposed model for two periods. First period spans from January 05, 1990 to May 09, 2014 while other starts from January 05, 2001 through May 09, 2014. Both periods were divided into two sections: 1) training, where 80% of data is used and 2) testing, where the rest is used. As a result, we not only found a high correlation between predicted and real data but also confirmed that high frequency data provides better results.

3 - Forecasting intraday arrivals at a call centre using neural networks: forecasting anomalous days
Devon Barrow, Nikolaos Kourentzes

A key challenge for call centres remains the forecasting of high frequency call arrivals collected in hourly or shorter time buckets. These forecasts are required for decisions concerning the scheduling, hiring and training of staff. In addition to the high frequency nature of call arrival series and the complex seasonal patterns, including the multiple seasonal cycles, call arrival data often contain a large number of anomalies, driven by holidays, special events, promotional activities and system failures. This study presents an approach based on artificial neural networks (ANNs) for forecasting intraday call arrivals. In so doing, we empirically evaluate alternative methodologies for modelling and forecasting outliers in high frequency data, which span over several periods, addressing a gap in research of practical significance considering the difficulty and the cost associated with manual exploration and treatment of such data. We assess the performance of different ANN modelling methodologies in terms of the accuracy with which normal and outlying periods are modelled. Multi-period outliers are modelled using alternative encodings ranging from binary dummy variables to functional profiles, as well as segmenting the series to separate it into outlying and normal days. Results show that ANNs outperform conventional benchmarks and are capable of modelling high frequency outliers using relatively simple outlier modelling approaches.

4 - Initialising neural network weights for time series prediction - an empirical evaluation of different methodologies
Sven F. Crone

Artificial neural networks require multiple initialisations of their starting weights for training, as the learning algorithms used for nonlinear parameter optimisation regularly converge into local minima. As the identification of suitable network weights is of preeminent importance in learning the classification or regression task at hand from a given dataset, a number of methodologies have been proposed to aid the learning process in setting initial starting weights. In addition to the standard procedure, using starting values drawn at random from a uniform distribution constrained to a narrow interval around zero, e.g. [-0.5; 0.5], a number of alternative initialisation methodologies have been proposed by Nguyen-Widrow, Drago-Ridella, Wessels-Barnard, and LeCun, which promise enhanced learning accuracy, efficiency and / or robustness. However, although these techniques have been evaluated on classification tasks for multilayer perceptrons, they have not yet been assessed on tasks of time series prediction and forecasting. This paper seeks to remedy this omission and assess the effect of different initialisation techniques in an empirical evaluation on real-world

time series data, using a representative experimental design of fixed-horizon forecasts across multiple rolling time-origins, and using robust error metrics. The results suggest that the selection of an adequate initialisation methodology has a significant impact on forecast accuracy, robustness and efficiency

■ MC-77
Monday, 12:30-14:00 - Collins Insight Institute

Behavioural issues in simulation modelling and use

Stream: Behavioural Operational Research
Invited session
Chair: *Duncan Robertson*

1 - Generating insights in a simulation project: the consultant's perspective
Stewart Robinson, Anastasia Gogi, Antuela Tako

It is often said that simulation interventions generate insights, but there is little empirical evidence to substantiate this claim. A qualitative study is performed to identify the key factors that support clients in generating insights. Ten business simulation consultants are interviewed. Using open-ended questions, the consultants describe projects in which clients have learned from simulation. Two general themes of learning emerged from the analysis of the transcripts: learning about modelling and learning as improved understanding. The latter is further divided into learning as Aha! moments and general learning. We specifically focus on learning as Aha! moments to identify the key elements of a simulation intervention that lead to insights. The analysis uncovers behavioural issues that are closely associated with the experience of Aha! moments. The analysis also shows that the quality of the process is more important than the quality of content in this context. The models are used as a means of thinking rather than as tool for prediction, with clients generating insights from the 'wrong', or even no, simulation model. This research contributes towards a better understanding of behavioural issues in simulation projects.

2 - A different outlook on stock-flow tasks. Using eye tracking methodology to explore eye movements of problem solvers.
Hubert Korzilius

Behavioral operational research is vital to understand aspects of system dynamic systems such as accumulation (Hämäläinen, Luoma, & Saarinen, 2013). In addition, "more attention to the analysis of the behavioral human factors' [...] is needed "to improve the OR-practice of model-based problem solving' (p. 623). Veldhuis and Korzilius (2012) propose to do eye tracking research to more precisely establish how individuals view graphs used in problem solving tasks and how they process the information contained in the graphs. In the current research we use eye tracking to reveal the relation between viewing and answering behavior when solving a system dynamics stock-flow task. In this eye tracking study we build onto previous research (Korzilius, Raaijmakers, Rouwette, & Vennix, 2014) on think aloud experiments by answering the RQs: which viewing patterns are used while solving the Department store task? Do viewing patterns prelude answering categories, and if so, how? We found viewing patterns in which areas of graphs of the Department store task were processed in two cycles. Four distinctive groups were found that differed in viewing patterns and answers given. Certain viewing patterns preluded answers, correct as well and correlation heuristic, especially in terms of frequency and duration of viewing parts of the graphs. These insights present a different outlook on stock-flow tasks and their use for behavioral operational research.

3 - An agent-based model of knowledge transferal
Duncan Robertson, L. Alberto Franco

We set out a model of inter-team knowledge evolution through intergroup interaction. We introduce facilitation into the model and show how different models of facilitation create different results in group members' knowledge.

4 - Value Creation Studies: An Emerging Approach To Co-Producing Business Change Through Projects
Gary Bell

This paper offers the idea of Value-Creation (VC) studies which combines methods (associated with Soft OR) and techniques (associated with Accounting and Finance) to understanding business change through a proposed project. Many organisations facilitate change through projects. However, the frequency of unsuccessful projects led to the Management of Projects ('choosing the right project' and 'doing the project right') concept. We outline this notion for it underpins new Project Management thinking. The Business Case is the orthodox approach to selecting the project, and is rooted in the Accounting and Finance discipline. The establishment of soft methods augmented with the thinking of Ackoff and Checkland establishes limitations of the Business Case approach. Additionally, the notions of Value Creation and Co-Producing derived by Normann are described, which engenders the need for a richer approach - thus, the inception of VC Studies. A VC study is undertaken to explore a proposed postgraduate business course website. The combination of qualitative System Dynamics and Holon Rich Pictures informs our requirements and the development of a Dynamic Cost/benefit spreadsheet model. Comparing and contrasting the various models (explaining new business situation (S1) with business-as-usual S0) informs our systemic understanding of the 'added value' of the proposed project. Finally, limitations this approach are highlighted which guides future research.

■ MC-78

Monday, 12:30-14:00 - Architecture AR201, Level 2

Game Theory and Social Networks

Stream: Game Theory and Social Networks
Invited session
Chair: *Juan Tejada*

1 - Satisfaction in oblivious and non-oblivious influence decision models
Maria Serna, Xavier Molinero, Fabián Riquelme

An opinion leader-follower (OLF) model is a two-action collective decision-making model for societies, including opinion leaders, exerting certain influence over the decision of other actors; followers, that might be convinced to modify their decisions, and independent actors[1]. We extended the OLF model by introducing two collective decision-making models associated with influence games [2], the oblivious and non-oblivious influence decision models. The difference is that in oblivious influence models the initial decision of the actors that are neither leaders nor independent is never taken into account while in the non-oblivious it is taken when the leaders cannot exert enough influence to deviate from it. The satisfaction measure, for an actor in a decision-making model, is the number of society's initial decisions for which the collective decision coincides with the initial decision of the actor. We show that computing the satisfaction measure is #P-hard in both oblivious and non-oblivious influence decision models. We present two subfamilies, fpr both types, of influence decision models in which the satisfaction measure can be computed in polynomial time.

[1] R. van den Brink, A. Rusinowska, and F. Steffen. Measuring power and satisfaction in societies with opinion leaders: dictator and opinion leader properties. Homo Oeconomicus,28:161—185:2011. [2] X. Molinero, F. Riquelme, and M. Serna. Cooperation through social influence. EJOR,242(3):960-974,2015

2 - Loss allocation in energy transmission networks
Gustavo Bergantinos, Julio González-Díaz, Ángel Manuel González Rueda, María P. Fernández de Córdoba

In this paper we study a cost allocation problem that is inherent to most energy networks: the allocation of losses. In particular, we study how to allocate gas losses between haulers in gas transmission networks. We discuss four allocation rules, two of them have already been in place in real networks and the rest are defined for the first time in this paper. We then present a comparative analysis of the different rules by studying their behavior with respect to a set of principles set forth by the European Union. This analysis also includes axiomatic characterizations of two of the rules. Finally, as an illustration, we apply them to the Spanish gas transmission network.

3 - A non cooperative approach to sharing delay costs in a PERT network
Leticia Lorenzo, Gustavo Bergantinos

Suppose that we need to carry out a project, involving several activities, that must be completed in a certain order. Some activities can be performed in parallel while other activities must be performed sequentially. This situation is modeled by a directed graph. In our problem there is a Planner that coordinates the project. We assume that each agent (firm) is in charge of exactly one activity. We propose a non-cooperative approach to PERT problems with a non-cooperative game in extensive form with 2 stages: - In the first stage the planner decides the penalty by unit of delay to be payed by the agents that have delayed in case the project is delayed. In case of no delay of the project, despite some agents have a delay in their activities, there is no punishment at all. - In the second stage, the agents decide how much effort to put on their activities. The bigger the effort the lower the delay in the activity is. We study the equilibria of this game.

4 - Evaluating organizational leadership in social networks
Juan Tejada, Elisenda Molina, Ramón Flores, Anna Khmelnitskaya

In relation with the problem of team formation in expertise social networks, we propose a value for directed graph restricted TU games - the Average Forest Value, AFV- when influence relations represent the ability of two agents for collaborating effectively when one of them acts as a leader of the work of both. In this way, we measure the ability of each agent to lead working teams - which is related with his position in the social network - when the performance of each group is also taken into account and it is captured by an appropriate TU game. We also analyze the right notion of efficiency in this setting, and we introduce the concept of network productivity, as a measure of the ability of the structure to promote the formation of productive teams.

■ MC-79

Monday, 12:30-14:00 - Architecture AR310, Level 3

OR for Public Health III

Stream: Operational Research for Public Health
Invited session
Chair: *Christine Currie*
Chair: *Honora Smith*
Chair: *Leonid Churilov*

1 - A goal programming approach to analyse the differences between the current Spanish diet and the Mediterranean Diet
Laura Delgado Antequera, Fátima Pérez, Monica Hernandez, Pablo Lara Vélez

The present research seeks to provide a comparative analysis of the differences between the nutritional consumption habits in Spain and one of the most expanded diets, due to its quality, the Mediterranean Diet. This is obtained by developing a goal programming model which minimises the deviations between the current Spanish consumption and the Mediterranean standards, taking into consideration budget constraints and minimal nutritional requirements. The data base has been collected from the Ministerio de Agricultura, Alimentación y Medio Ambiente, of the Spanish Government.

2 - Improving the Efficiency of a Breast Cancer Diagnostic Clinic
Christina Saville, Honora Smith, Navid Izady

This talk describes data mining and appointment capacity planning approaches which aim to improve the efficiency and effectiveness of a London hospital's breast cancer diagnostic clinic. In order to encourage earlier diagnosis of cancer, the NHS standard is that patients should see a specialist within 2 weeks of being urgently referred with breast symptoms or suspected cancer by their general practitioner [GP]. Currently, there is only one route by which GPs can refer patients for breast cancer diagnostics at the hospital, regardless of the urgency. The hospital runs a one-stop breast cancer diagnostic clinic where patients receive a physical exam by a specialist breast surgeon followed by a series of diagnostic tests on the same day. Data mining classification

methods are presented to predict a patient's risk level and which tests they will require, based on GP referral notes. The aim is to improve efficiency of the clinic while accounting for different patients' needs. Strategies are discussed to help the hospital more consistently achieve the two-week-wait target, while reducing patients' waiting times in the clinic. Finally, the project aims to provide insights into what factors affect which hospital a GP surgery refers their patients to for breast cancer diagnostics.

3 - Brain attacks in children: Operations research modelling for appropriate identification of paediatric stroke patients
Leonid Churilov, Babak Abbasi

Stroke is one of the three top causes of death and disability in the world. The timely recognition of stroke is essential to ensure appropriate acute management. Recent paediatric studies have confirmed significant diagnostic delays due to lack of recognition of stroke symptoms by attending physicians. Diagnostic delays may relate to lack of consideration of stroke as a diagnosis in children presenting with acute focal neurological symptoms or headache. It is currently unclear whether adult brain attack protocols can be implemented in the paediatric population due to limited understanding of the spectrum of symptoms and signs of brain attacks and the lack of data about the probability of stroke.

The objective of this research is to develop and validate an OR model to support decision making in appropriate identification of children with stroke. This is achieved by systematically evaluating various statistical and machine learning tools including regression, CART, neural networks, and support vector machines, using the data collected for the Children Brain Attack project at the Royal Children's Hospital in Melbourne, Australia. The appropriateness for the task of six candidate decision support models based on various demographics and process-of-care variables, as well as clinical signs and symptoms, is investigated. Conducted in close collaboration with clinicians, this study is used to support the clinical stakeholders in developing a protocol for children stroke care.

■ MC-80
Monday, 12:30-14:00 - Architecture AR311, Level 3

Open Vehicle Routing and Route Minimization

Stream: Transportation Planning
Invited session
Chair: *Tobias Buer*

1 - Minimizing the Maximum Distance with Penalizing Unused Capacity in Open Vehicle Routing Problem
Gamze Tuna, Melis Alpaslan, Erhan Tonbul, Nihal Erginel

Open vehicle routing problem (OVRP) is a well-known problem in that the vehicles do not return to the depot after servicing the customers. The classical OVRP aims to minimize the total travelling distance under the vehicle capacity constraints. Because the total cost increases when the total assigned demands of a vehicle is below the capacity, it is better to maximize the usage of the vehicle capacity throughout its route. Therefore the average used capacity of the vehicles is taken into account in this study. Minimizing the maximum distance from depot is important; because the routing cost is defined as the maximum distance of each route in real life OVRP. In this study, minimizing the total travelling distance, the costs of maximum distance from depot and the penalty cost of unused capacity are considered as the objective of the problem.

2 - Solving Open Vehicle Routing Problems with Real Life Costs via Genetic Algorithm
Erhan Tonbul, Gamze Tuna, Nihal Erginel, Melis Alpaslan

Open vehicle routing problem (OVRP) is one of the most studied subtopics of vehicle routing problems and usually regarded as minimizing the total distance travelled by vehicles not returning to the depot. But in real life problems, there are some other aspects to deal with. One of them is the pricing method of logistic firms. Actually most of these firms do not do the pricing according to the total distance

travelled. Mostly, the main cost considered in a route is taken as the pre-determined cost of travelling to the last point in that route. Stop-by costs, which can be defined as costs taking place when a vehicle goes to the points between the depot and the last point, and deviation cost should be added to reach total cost. Deviation cost can be thought as the extra distance travelled in a route compared to the distance taken directly from the depot to the last point of that route. When we consider last point costs, stopping-by costs and deviation costs as the main costs in OVRP models, more reasonable and realistic solutions can be obtained. Since metaheuristic approach is a good way of having good solutions in a short period of time, the method of solution is determined as genetic algorithm. Using metaheuristics, especially genetic algorithm, works great in such big solution spaces with such objective functions, like the one suggested by this study, that has higher complexity than traditional ones.

3 - Cluster-based Routing for Small Package Delivery
Timo Hintsch, Stefan Irnich

In this presentation we introduce a planning problem for small package delivery. Given is a grouping of private households into clusters. The service region consists of given service territories (with several clusters) and additional flexible clusters. The task is to assign flexible clusters to routes serving a single service territory and to route the vehicles that perform the package delivery. It is assumed that each cluster must have been served in total before the next cluster can be served. This decomposes the routing problem into two subproblems, the routing inside a cluster and the routing between clusters. The first task requires the solution of several postman problems, one for each possibility to start (entrance) and end (exit) the route through the cluster. The chosen start-end-pair of the clusters also affects the second subproblem for routing between clusters. It can be modelled and solved as generalized VRP (GVRP).

4 - An Optimization Model to 3D Route Planning for Air Navigation Systems
Shadi Sharif Azadeh, Yousef Maknoon

In recent years, commercial aviation institutions have shown interests to use autonomous systems to find their paths. Especially, for small sized aircrafts in Europe this is critical as the path finder software could be installed on smart phones. In addition, a path finding algorithm that can reduce the fuel burn and travelling time is crucial for such aircrafts even for short leg flights. In this research, a mathematical programming approach is proposed for 3D air planning algorithm. There are many obstacles that need to be avoided, such as airspaces, storms as well as mountains. We have validated our model using the actual data.

■ MC-82
Monday, 12:30-14:00 - Architecture AR401b, Level 4

Health Care Modelling

Stream: Healthcare Service Improvement
Invited session
Chair: *Harry Venables*

1 - A Modelling Approach for Healthcare Waste Collection and Disposal to Mitigate Its Hazardous Effects
Zeynep Gergin, Şakir Esnaf

The growing amounts of healthcare waste highlight the requirement of precocious care due to its infectious feature. The health impacts include carcinogenic effects, reproductive system damage, respiratory effects, central nervous system effects, and many others. Environmental impacts are ground and air pollution, which consequently cause various hazards for living species. Furthermore, during the collection and disposal process, some pollutants that should be controlled, such as carbon dioxide emission, are also produced. Especially in large cities like İstanbul the collection of medical waste and transferring it safely to the treatment and disposal facilities require intensive care considering the traffic jam caused by the large population. Due to the geographical location, the medical wastes are collected on both sides of the Bosphorus using separate truck fleets, and transferred to the treatment facilities on the European side. This research aims to model the vehicle routing of waste collection of Istanbul. The study proposes local treatment facilities close to the pre-clustered hospitals on both sides. A multi-stage model assigns vehicles to the clusters and optimizes their routes both

for collecting waste in the clusters and delivering them to the treatment units. Achieved improvements that will mitigate the hazardous effects, such as carbon dioxide emissions causing carcinogenic and respiratory effects, together with ground and air pollution impacts are concluded.

2 - Evidence-based decision-making: re-usable simulations to test the impact of interventions on 5-year disease prevalence, cost of care, and patient mortality
Claire Cordeaux

The session will explore how disease progression modelling can be developed and reused multiple times to support health services decision-making. Using similar methodologies to model identification and treatment of HIV and Hepatitis C, the first in the USA and the second in the UK, we will show how simulation models can quickly scope and test the key strategic and operational questions facing health systems as they make decisions on patient pathway interventions. Both HIV and Hepatitis C conditions are chronic, but treatable if patients can be identified and treatment adherence improved. Only 2% of Hepatitis C patients in the UK are diagnosed and undiagnosed patients deteriorate and suffer from liver disease if left untreated. HIV patients are living longer with treatment, but in the USA, 30% are still undiagnosed and will develop complications. In both cases, healthcare payers and providers need to balance the aims of improving patient outcomes with the cost of additional screening programmes and treatment and the staffing requirements to deliver the service. The presentation will outline in depth the approach to developing the simulation models, the engagement with the end user, the results from the simulation and their impact in real life decision-making. It will reflect on how disease modelling can be developed for reuse with multiple healthcare payers and providers.

3 - Neural Networks for Modelling Power-Duration Relationships
Harry Venables

Elite and professional cyclists have used power meters since the late 1990s. The advancement, development and reduced cost of this type of technology have allowed power meter based training to be adopted by various non-professional groups. Data collected by power meters fall into the area of 'Big Data', and the modelling of power duration seen as crucial information concerned with aspects of training, potential performance and competitive objectives.

Presently available models for power durations are normally based on measurable physiological markers, with the exception of an exponential curve-fit model (Pinnot & Grappe, 2011). However, as indicated by Coggan (2013), none of these successfully model the entire power-duration relationship and thus a more reliable model needs developing.

The aims of this work are to develop a power-duration models using a neural network curve fitting approach. A neural network is a useful tool for modelling non-linear relationships. The objective is to develop single hidden layer perceptron models with as few neurons as possible, whilst achieving best fits using root mean square and relative error metrics. A series of nineteen annual power-durations data sets are used to derive the models.

■ MC-84

Monday, 12:30-14:00 - Architecture AR403, Level 4

Data Mining in Bioinformatics

Stream: Computational Biology, Bioinformatics and Medicine
Invited session
Chair: *Giovanni Felici*

1 - Graph Databases in Bioinformatics
Maciej Milostan

Effective storage and data mining capabilities are crucial for successful analyses and comparisons of complex systems and their components. However the most common forms of storing data in many bioinformatics experiments are relational databases and, surprisingly, flat files. Both forms have serious drawbacks that, in case of multiple relationships, can cause decrease in computation speed, complications in data representation or increase of programming efforts. Thus in recent years

we observe growing interest in NoSQL databases, especially graph databases[1].

Graph databases stores data in schema less manner, where data objects are represented as vertices and relationships as edges with tags and properties. Multiple types of edges and vertices can coexist. Graph databases may be an elegant, intuitive solution in the case where multiple types of relations or interactions exists between various kinds of objects.

During the talk, application of Neo4j[2] database for selected bioinformatic problem (e.g. Protein-Protein Interaction networks) will be shown. The added value will be a set of technical remarks showing how to import data to Neo4j in effective way, and how to write fast queries in Cypher language.

References: [1] Ch. Have and L. Jensen, Are graph databases ready for bioinformatics? doi:10.1093/bioinformatics/btt549 [2] http://neo4j.com/

2 - Multi-objective Hierarchical Clustering of Complex Knowledge with Support of Ontology, Euclidean and Graph-based Distances
Marek Ostaszewski, Piotr Gawron, Pascal Bouvry

Management of rich expert knowledge is a challenging task that should enable intuitive and informative representation and exploration of the knowledge. For that reason, contents of knowledge repositories are mapped to views defined as diagrammatic representations, in which Euclidean distance models associations between elements. Important additional information is often available; e.g the network structure of the connected facts, or associated ontologies. These aspects can be used to improve visualization and to generate hierarchical organization schemes of the underlying complex knowledge. We investigated several approaches for knowledge representation in a well-defined, complex knowledge repository that concerns a human disease. Knowledge in this repository is represented as a heterogeneous network, describing the underlying biomedical metadata. From there, we extracted information on geometric coordinates, network structure and annotations by a domain-specific ontology. Then we used these characteristics to explore and evaluate different hierarchical clustering schemes as overlays to the two-dimensional view. Our results indicate that multi-objective hierarchical clustering allows to aggregate biomedical data into informative structures of different granularities. By exploring different objectives we obtained profiled representations of the underlying knowledge, which were evaluated against expert-provided annotations of the same dataset. We believe that this approach

3 - All that Glitters is not Gold: Rectifying Statistical Significance for Biological Inference
Mario Guarracino, Kumar Parijat Tripathi, Daniela Evangelista, Giovanni Felici

The analysis of high throughput gene expression patients/controls experiments is based on the determination of differentially expressed genes, using standard statistical tests. Once a panel of genes is determined, it is used to detect biological enriched pathways, containing a statistically significant number of genes whose expression levels are altered between patients and controls. Analysis of metabolic pathways with in the large-scale data sets helps us to undermine the additive effects of multiple functionally related genes, which are difficult to detect by focusing on traditional gene analysis. Usually the set of determined pathways contains elements that are clearly not related to the biological condition under study. This is due to the fact that the statistical significance is not connected with biological causality, and therefore the detected pathways are above a certain threshold only because they contain a sufficient number of altered genes. We analyzed the gene expression data for different types of cancer downloaded from TCGA (The Cancer Genome Atlas). We identify the differentially expressed genes in each respective cancer and carried out the KEGG pathway annotation to create the pathway profile matrix. To refer to the problem of statistical significance with no or low biological inference for the given pathway annotation in cancer expression data, we propose a novel methodology based on mathematical programming, and show the results of numerical experiments.

4 - Modelling and Analysis of High-throughput Data in Cancer Research and in Microbial Ecology
Antoine Buetti-Dinh, Ran Friedman, Mark Dopson, Igor V. Privkin

Today's high-throughput technologies are increasingly used from clinical research to microbial ecology, and the wealth of data produced by these techniques defies straightforward interpretation. Novel methods and computational tools are necessary to optimize data mining, complement lack of data where necessary and retrieve desired information. This is essential to transfer the information furnished by these new technologies into practical applications such as combined cancer therapy and microbial bioleaching. Using tools like Bayesian analysis and clustering methods in a data-driven approach, we reverse-engineer experimental datasets into biological interaction networks. We further investigate the results using an in-house developed computational platform for sensitivity analysis of biological networks. Our simulations are based on principles of physical biochemistry and enzyme kinetics to represent activation/inhibition networks under simplifying assumptions that allow to deal with real-life scenarios. Both in cancer biology and microbial ecology, biological networks are abstracted from an experimental system and modelling is subsequently used to optimize complex processes by controlling key nodes of the network. This allows us to make cancer therapies more specific to drug resistance, or to make the process of copper extraction from mining waste more efficient and ecologically friendly.

Monday, 14:30-16:00

■ MD-01

Monday, 14:30-16:00 - Barony Great Hall

Keynote Lecture: Horst Hamacher

Stream: Plenary, Keynote and Tutorial Sessions
Keynote session
Chair: *Sibel A. Alumur*

1 - Operations Research Models in Evacuation Planning
Horst W. Hamacher

Due to the variety of problems which need to be tackled, evacuation planning is an excellent field for the development of theory and implementations of Operations Research (OR) models. In this presentation we will present several types of evacuation problems, show the interplay between various OR disciplines and focus on some specific optimization techniques which have been developed in the past years to model evacuation problems as accurately as possible.

■ MD-02

Monday, 14:30-16:00 - Barony Bicentenary Hall

EURO Excellence in Practice, part II

Stream: EURO Awards and Journals
Invited session
Chair: *Luca Maria Gambardella*

1 - Mathematical Programming-Based Sales and Operations Planning at Vestel Electronics
Z. Caner Taşkın, Semra Agrali, Ali Tamer Unal, Vahdet Belada, Filiz Gokten-Yilmaz

We investigate the sales and operations planning (S&OP) process at Vestel Electronics, a major television manufacturer located in Turkey. The company has a large product portfolio because its products have many configuration options, and its product portfolio changes rapidly as a result of technological advances. Demand volatility is high, and materials procurement requires long lead times. Hence, the S&OP process is critical for efficient management of company resources and its supply chain and to ensure customer satisfaction. We devise a mathematical programming formulation for Vestel's S&OP process and describe our experience in implementing a decision support system (DSS) based on our optimization model. We fully implemented and deployed our DSS at Vestel, which has used it every day since 2011.

2 - Strategic Airport Capacity Management
Simon Martin

Strategic Airport Capacity Management (Strategic ACM) is a groundbreaking capability for airport capacity analysis that was developed and deployed in 2014. London Heathrow is the first airport to be using the service and has achieved immediate benefits, most notably the creation of the first brand new early morning arrival runway slot at the airport since 1996. This presentation will describe the data analysis and simulation tools that make up Strategic ACM and the benefits that have been achieved so far.

3 - Calibrated Route Finder — for Improved Transport Efficiency
Patrik Flisberg, Mikael Rönnqvist, Gunnar Svenson

Calibrated Route Finder is a system that establishes the most efficient route forlogging trucks to be used for invoicing of the transportation work in Sweden. The route selection depends on many road features, such as length, road class, curvature, hilliness, speed limit, road width and many more special considerations. It is very difficult to manually find a suitable weighting of the road features. Our approach is to use an inverse optimization formulation with a large number of agreed and measured so-called key routes that form a set of optimal solutions of a minimum cost routing problem. The system has gradually been

developed based on reporting and requests from the users. Recent implemented development is to include curvature and hilliness as road features. These features are developed using highly detailed spatial data from a national road database together with detailed road measures from special trucks. Particular care needs to be taken to errors and missing data in the large road database. The system is gradually introduced amongst all forest companies in Sweden, and is currently used to invoice about 50% of all 2 million forest transports done annually. This corresponds to 80 million tonnes with a transportation cost of 700 million Euro. There are large savings both in quantitative and qualitative terms. For the latter the system contributes to standardization, fairness and simplicity and for the former reduced administration, costs and greenhouse emissions.

■ MD-03

Monday, 14:30-16:00 - TIC Auditorium A, Level 2

MAI: One-to-one mentoring for practitioners

Stream: Making An Impact 2 (MAI 2)
Invited session
Chair: *Rosemary Byde*

1 - One-to-one mentoring for practitioners

In this session, you can receive 20 minutes of one-to-one mentoring with an experienced practitioner, on issues you may be facing in your practice, career or development. Possible issues may include: Managing your development and career ● Switching sectors ● Changing jobs ● Transitioning from technical 'doer' to managing technical teams ● Finding the right mentor ● Making contacts, building a network ● Getting recognition when you're a technical expert ● Writing a good CV and doing well in interviews

Managing your team ● Recruiting, training, rewarding and retaining the right people ● Making sure your modellers spend their time modelling ● Delegating without tears ● Inspiring others

Making more of an impact ● Selling your services ● Communicating technical results ● Influencing non technical people ● Getting projects implemented

To get the most from the session, you should do some preparation in advance: ● Think about a problem you'd like help and advice on ● What would you like to know from your mentor? ● Expect to ask questions ● Show an interest in your mentor.

This session is only available to people who have signed up in advance via the 'Making an Impact' (MAI) desk. It is one of three similar sessions.

■ MD-04

Monday, 14:30-16:00 - TIC Auditorium B, Level 2

Retail Inventory Management III

Stream: Demand and Supply in Retail and Consumer Goods
Invited session
Chair: *Christian Larsen*

1 - Inventory Control with and without Partial Deliveries
Christian Larsen

An inventory system is operated as a base stock system under a compound Poisson demand process. Besides having inventory and backorder costs there is also a cost incurred for each order that is delivered partially (irrespective of whether some items in the order are delivered on time or whether they are all delivered late but with different delivery times). We compare this to another scenario where it is forbidden to make these partial deliveries, thus at the same time there can be a positive on-hand inventory and a positive backlog. The derivations for the latter model apply the unit tracing methodology of Axsäter (1990). We

examine the threshold value for the delivery split cost which makes the two models perform equally well and how it depend on the parameters in the model.

2 - Generalized Joint Replenishment Model for Multi-Retailer Scenario under VMI
Nishant Kumar Verma, Ashis Chatterjee

Vendor managed inventory (VMI) is a well-established supply chain practice wherein the supplier is responsible for managing the inventory at the retail points. In particular, the supplier takes care of, when to order and how much to order on behalf of the retailers. This paper considers a single supplier — multiple retailer setting where supplier takes inventory replenishment decisions for retailers such that the replenishment quantities are within an upper bound that is mutually agreed upon in the VMI contract. We develop a non-linear mixed integer programming model to compute the optimal replenishment frequencies and quantities for the retailers, such that the total system cost is minimized. A conceptual and numerical comparison is made with the existing models in the VMI literature. The proposed model is found to perform better, thereby establishing the generalization among the class of models. We also propose an efficient heuristic for solving the proposed model by utilizing the concept of cycle ratio (setup cost/holding cost * demand) thus reducing the computational time drastically.

3 - MDL-Based Interval Forecasting with Limited Data in Fast Fashion Industry
Wei Ming

Sales forecasting is a critical task for managers in fast fashion industry. However, forecasting the exact selling quantity is usually difficult and inaccurate due to the short life cycle of fashion products, managers are sometimes more interested in predicting the interval within which the selling quantity may lie. Interval prediction is very useful for mangers to control the stock level and price the products. In this paper, we propose a novel machine learning-based model for two major objectives, namely 1) to estimate the prediction interval of the sales; 2) to resolve the issue in interval forecasting caused by insufficient volume of data in fast fashion industry. In our proposed model, bootstrap technique has been adopted to construct the prediction interval for neural network. Moreover, to deal with the insufficiency of training data, the minimum description length criteria has been employed in the neural network training process to select the most suitable model for the data. Our empirical results demonstrate that the proposed model outperforms previous models with similar objectives.

■ MD-05

Monday, 14:30-16:00 - TIC Auditorium C, Level 2

OR for Energy Economics

Stream: OR for Energy and Resource Efficiency
Invited session
Chair: *Christoph Weber*
Chair: *Thomas Kallabis*

1 - CHP and electric heater in a highly renewable electricity system
Gerda Schubert

The increasing electricity production from fluctuating renewable sources such as wind and solar power causes a need for more flexibility. At the same time a decarbonisation not only of the power system but also of the heating market is necessary. The combination of these challenges leads to certain frictions, but it also offers new opportunities for synergies. Rising shares of fluctuating renewable electricity on the electricity market compete with electricity produced in combined heat and power (CHP) plants already today and this competition will intensify within the next decades. At the same time heat storages can increase flexibility of CHP plants and power-to-heat technologies can help to integrate renewable electricity from the electricity market into the heat market. The assessment in this paper is based on an integrated least-cost optimization of the heating and electricity market in an hourly resolution up to the year 2050 with an extended version of PowerACE-Europe. Interactions between renewable electricity, CHP and electric heaters can be assessed, as the capacity development of renewables is integrated in the optimization. Different scenarios with a focus on Germany are analyzed. The results show that economically

optimized CHP shares are high in the medium term, but decrease with increasing CO2-prices and renewable shares on the electricity market. Power-to-heat technologies in heat grids evolve significantly in systems with high renewable electricity shares.

2 - Integrated bidding and operating strategies for wind farm-energy storage systems
Huajie Ding, Pierre Pinson

Due to their flexible charging and discharging capability, energy storage systems (ESS) are thought of as promising complement to wind farms participating in electricity markets. We put forward integrated day-ahead bidding and real-time operation strategies for a wind-storage system, in order to perform arbitrage and to alleviate wind power deviations from day-ahead contracts. Two strategies are developed with one-price and two-price balancing markets separately. Both strategies are built to determine optimal offers taking into account expected wind power forecasting errors and the power balancing capability of the ESS. For the former case, a reserve-based bidding and operation strategy is modeled as a mixed integer nonlinear optimization formulation. A modified gradient descent algorithm is designed to solve this nonlinear problem. Linear decision rules are chosen as the real-time control strategy in the latter case, as it can fully utilize past and current price and wind power information, so as to perform arbitrage. A number of case studies allow validating the proposed strategies and corresponding algorithms, in terms of computational efficiency and optimality. Compared to the existing, the proposed strategies yield increased economic profit, regardless of the temporal dependence in wind power forecasting errors.

3 - A parsimonious fundamental model for wholesale electricity markets - Analysis of the plunge in German futures prices
Thomas Kallabis, Christian Pape, Christoph Weber

The German electricity market has seen a plunge in wholesale prices in recent years. From 2008 until 2013, base prices dropped by more than 40%, leading to burdens for affected actors and policy makers. This paper investigates driving factors of the price decrease. We determine the fundamental component of electricity base future prices for the front-year contracts 2008-2013. By using a simplified stack model we are able to quantify the impact of specific fundamental factors. The price difference between the fundamentally expected and the actual futures prices can then be attributed to risk aversion, potential speculation or policy uncertainty. Policy uncertainty refers to the nuclear phase-out and deviations between the expected and actual renewable energy feed-in caused by the renewable support scheme in Germany.

Our methodology is based on a parsimonious stack model, where the electricity supply curve is approximated by piecewise linear functions for the main technologies. It turns out that this model captures a large amount of the variations in electricity futures prices, indicating that electricity prices are mainly driven by fundamental factors. We quantify which of the factors fuel prices, renewable feed-in, conventional generation capacities and demand contributed most to the observed price slide. Our investigation points out that misjudgments regarding renewable capacity additions are not the single crucial reason for the plunge in wholesale electricity prices.

4 - Modeling Capacity Expansion under Uncertainty in an Oligopoly using Indirect Reinforcement-Learning
Fernando Oliveira, Manuel Luis Costa

We model capacity expansion in oligopolistic markets, with endogenous prices, under uncertainty, considering multiple production technologies. In such a complex environment characterized by bounded rationality of the firms, is capacity expansion the result of an explicit optimization procedure or does is arise from a learning process? How can learning occur when the number of investment decisions is so limited? We propose indirect reinforcement-learning to model the interaction between the pricing and capacity expansion (and divestment), in the context of an oligopolistic game. We apply our model to the analysis of the Iberian electricity market, considering multiple technologies, and focusing on how subsidies, CO2 emission prices and, possibly, lower gas prices, affect the capacity expansion policies.

5 - Large Scale Modeling and Analysis of "The Turkish Energy System'
Mine Isik, Gürkan Kumbaroglu, Ilhan Or, Kemal Sarica, Gönenç Yücel

It is inevitable that continued GHG emissions will result in greater damage on the climate system. Hence, nations aim to implement policies concerning this carbon emission problem. Various studies accentuate the rapid growth of GHG and other pollutant emissions and reveal that national policy makers are in urgent need of an appropriate energy-economy-environment modeling that could give accurate projections on future forecasts. This study aims to provide projections on Turkey's national energy sector by utilizing TIMES modeling approach which is a perfect-foresight, bottom-up, dynamic, LP framework. TIMES modeling elaborates interactions between economic activity, energy consumption and their effects on climate change. An updated TIMES database representing general energy system of Turkey from 2012 to 2062 in 5-year increments will be developed. Characterization of current and future technologies within database will be developed from IEA's 2012 Annual Energy Outlook Report and a project of Ministry of Energy and Natural Resources using economic indicators to generate accurate data. Public data sources, government agencies, and non-profit organizations will be used. The constructed model reveals the current behavior of the national energy sector. Scenarios featuring direct upper bound limitation on emission, carbon taxes, subsidies and renewable energies, expanded deployment of nuclear and/or CCS technologies with more positive future expectations are being experimented.

■ MD-06

Monday, 14:30-16:00 - TIC Lecture Theatre, Level 1

POM Applications II

Stream: Production and Operations Management
Invited session
Chair: *Engin Topan*

1 - Construction of low cost efficient experiment designs: a MIP model and solution approach
Vitoria Pureza, Lana Mara Santos, Pedro Oprime

Designing industrial experiments with low costs and good statistical properties is a key challenge for both researchers and practitioners. The main reason is the combinatorial nature of the problem and the possible conflict between these objectives. In this work we propose a MIP model and a solution method aiming to generate highly efficient, low cost 2k full-factorial and fractional-factorial designs, at the same time the independence of main effects to linear and quadratic time trends is enforced. We also show that the model can be easily extended to include constraints commonly practiced in manufacturing companies such as excluding specific experimental units and considering real or estimated costs of factor changes (rather than the number of factors changes) as a function of the factor. The proposed approach was implemented in a commercial optimization software and its performance evaluated for regular and non-regular designs from 12 to 64 experiments and 4 to 6 factors. Results indicate that the approach is capable of producing high quality designs regarding the objectives addressed within reasonably short computational times.

2 - A Multi-Stage Production Planning Model for a Stainless Steel Kitchenware Manufacturer
Berivan Şanlı, Ruhan Bayram, Tülin Aktin

The aim of this study is to plan the production of a kitchenware manufacturer that produces stainless steel products for various firms on a make-to-order basis. The company which is located in Istanbul has started producing these products in the 1980s. Currently, it has an area of 14,000 square meters and employs 300 workers.

The study will be performed to plan the production of the stainless steel pots that are produced for the customer having the highest priority in terms of work volume. The production process consists of 10 inter-related stages. A multi-stage, multi-product, and multi-period model will be developed to determine the optimal production volume of pots, amount of raw material required for production and workstation usage rates. Demand data of pots, workstation capacities, rework rates, raw material usage quantities and processing times per pot are some of the data that will be used in the model.

The proposed mixed-integer linear programming model aiming profit maximization will be solved using GAMS software and CPLEX solver. The results will then be discussed with the management, and their suggestions regarding the planning process will be incorporated in the scenario analysis section of the study.

3 - Multi-Item Spare Parts Inventory Planning with Selective Use of Advance Demand Information
Engin Topan, Geert-Jan van Houtum, Tarkan Tan

Motivated by a real-life application, we consider a multi-item, spare parts inventory system where it is possible to monitor critical components at a certain per-component condition monitoring cost (CM). This makes it possible to predict the quantity and timing of failures in advance for parts that are monitored. However, this information is imperfect because (i) it may turn out to be false, (ii) exact timing is not known and (iii) there are yet failures which cannot be detected in advance by monitoring. We propose a model with a general representation of imperfect demand information to determine which critical components should be monitored and how much stock should be kept for each component so that a given aggregate system availability is maintained. Our model also allows excess inventory on stock and on order to be returned to the central depot or external supplier at a certain return cost. We characterize the optimal ordering and return policy. Given the optimal policy, we propose a solution procedure based on the Lagrangian decomposition of the multi-item inventory model to determine the components to be monitored and also the optimal policy parameters for all parts. Through an extensive numerical study we investigate the value of (imperfect) information. Finally, we apply our model to case data of ASML, a manufacturer of lithography systems for the semiconductor industry and we show that the value of the imperfect information in their case is significant.

■ MD-08
Monday, 14:30-16:00 - TIC Conference Room 2, Level 3

Efficiency Models

Stream: OR and Real Implementation
Invited session
Chair: *Sebastián Lozano*

1 - A Universal Network DEA Approach for Series Multi-Stage Processes
Dimitris Despotis, Dimitrios-Georgios Sotiros, Gregory Koronakos

We present in this paper a general network DEA approach to deal with efficiency assessments in multi-stage processes. Our approach complies with the composition paradigm, where the efficiencies of the stages are estimated without a prior definition of the overall efficiency of the system. The overall efficiency is obtained by aggregating the stage efficiencies a posteriori. We use multi-objective programming as modeling framework. This provides us the means to assess unique and neutral (unbiased) efficiency scores and, if required, to drive the efficiency assessments effectively in line with specific priorities given to the stages. A direct comparison with the multiplicative decomposition approach on data drawn from the literature brings into light the advantages of our method and some critical points that one should be concerned about when using the multiplicative efficiency decomposition.

2 - Interactive Management of Unstructured Knowledge and Dynamic Processes
Hans L. Trinkaus

With the upcoming Internet (of Services, of Things) people, machines and devices get the ability to communicate. Systems, nearby and from around the world, are connected. They prompt information, offer services, send requests for support and trigger actions automatically, and thus require faster and tighter interactions between people involved. In all, the future asks to become highly flexible in handling unstructured knowledge and managing all kinds of dynamic processes. A resulting "collective intelligence' may emerge by providing tools enabling people to cooperate on a platform that supports straightforward information exploration and structured knowledge generation, assists ad-hoc process design and unlaboured process management, and guides, tracks and evaluates all approved user activities. The platform developed aims at these goals. Its GUI performs adaptive to different user types (laymen, experts) from various user groups (individuals, families, communities). Interaction is enabled via keyboard, finger, pen,

speech recognition, etc. Communication is facilitated as WEB dialogue, via E-Mail, Chat, etc. The tools provide single task and complete workflow templates to perform generation, production and exchange processes — w.r.t. knowledge, goods and services. Finally, decision making, quality assessment and performance evaluation are supported by an intuitively applicable software component using graphical means. Modules and prototypes will be presented.

3 - Banking Debt Collection Aided with a Markov Decision Process Optimization Engine
Leonidas Lymberopoulos

Financial institutions, such as banks and tax authorities, use empirical rules for deciding which collection action (e.g. email, phone call, letter, etc.) should be enforced on each delinquent customer. In this paper, we introduce a debt collection optimisation engine, whose goal is to find which collection actions should be applied at each collection stage in order to optimize the revenue to the financial institution. The paper provides simulation results that show the efficiency of the optimization engine in the process of debt collection. To solve the debt collection optimisation problem, we model the collection system as a Markov Decision Process (MDP). We then prove that the MDP is time homogeneous and first order, using 2 statistical tests on historical data (26 months traces of 91.064 customer records) from the debt collection department of a bank. Using the 26 months training data set, we derive the parameters of our MDP: the state transition probabilities and the collection action rewards. We then solve the finite horizon problem and obtain the optimal policies for a forecasting period of 4 months. Comparing the sum of actual rewards and the total revenue when the collection actions are proposed by our MDP solver for the 4-month forecasting period, the simulation results show that the MDP optimal policies yields to a 14,81% net gain of the total revenues, a big and promising improvement of the efficiency of the debt collection system.

4 - Exploring the Pareto Frontier of Regional Airports
Sebastián Lozano, Ester Gutiérrez

This research presents the results of an efficiency assessment of 21 regional airports located in 10 different European countries. It includes, in addition to traditional inputs such as runway area, boarding gates and apron stands, two novel variables: number of airlines and number of scheduled routes. Aircraft movement, passenger throughput and cargo handled are the three outputs considered. An output-oriented radial DEA model is used to estimate efficiency. A second stage regression of the efficiency scores found that ownership and hub airport status are significant factors that can explain variations in the estimated efficiency of the European regional airports. Thus, for example, hub airports seem to be more efficient than non-hub regional airports. An augmented weighted Tchebychef multiobjective optimization approach is used to explore the Pareto frontier, analyzing and visualizing the trade-offs that can be achieved between the different outputs.

■ MD-09
Monday, 14:30-16:00 - TIC Conference Room 3, Level 3

MAI: Cleaning, joining and trusting large datasets — practical techniques

Stream: Making An Impact 2 (MAI 2)
Invited session
Chair: *Martin Slaughter*

1 - Cleaning, joining and trusting large datasets — practical techniques
Martin Slaughter

Like many analysts, we and our colleagues were working with large, messy and disjoint datasets long before the term "big data' was coined. Creating a coherent dataset and knowing what it can (and can't) be used for with confidence becomes ever more important and this session invites practitioners to exchange practical advice on techniques to achieve this goal. This will be suitable for any analysts interested in this issue, from those who have long experience of grappling with messy data to those who are just beginning to confront the task.

■ MD-12

Monday, 14:30-16:00 - TIC Conference Room 4&5, Level 3

Long-term Energy Transition to Sustainable System

Stream: Long Term Planning in Energy, Environment and Climate
Invited session
Chair: *Nadia Maïzi*

1 - Environmental compliance in a world of Quixotes and Sanchos

Ana García-González, Francisco Cabo

This paper analyzes the compliance of economic agents with environmental rules settled to help maintaining a valuable environmental amenity. Since compliance is costly and the environmental quality is considered a public good, agents have an incentive to free-ride. However, the paper distinguishes two types of agents: for the standard agent (Sancho) this public good game is described by the prisoner's dilemma dominated by the non-compliance strategy. We assume that there exists an alternative type of agent, Quixote, who still has an incentive to free-ride. However, when others defect, he prefers compliance over mutual defection (a hawk-dove type of game). This second type of agent can be referred to as environmentally concerned. Compliance is analyzed as an evolutionary game with two distinct populations. The first question studied in the paper is to what extent the non-compliance equilibrium in the population of Sanchos can be affected by the existence of a population of Quixotes. More precisely, is it possible that some agents in the Sancho population imitate the environmentally-concerned Quixotes, leading them to comply in the long run?

2 - Modeling of Future Flexibilities in the European Energy System

Christoph Baumann, Jannik Breiter, Albert Moser

The energy transition in Europe leads to increasing requirements regarding the flexibility of the energy system. Especially due to the expansion of wind and solar power generation, the electrical residual load becomes more volatile and energy surpluses will occur in the long-run. Thus, increasing flexibility from generation and load as well as storages will be needed. The use of these sources is determined at the energy markets and competes with each other. In addition, long-term storage by Power-to-Gas (PtG) technology might further enhance the coupling of the natural gas and power system. This paper introduces a model for the combined simulation of the European markets for natural gas and electricity. The model is based on a cost minimization approach and uses multi-stage optimization with decomposition techniques. One main result of the simulation model is the hourly dispatch of generation and storage units for a consecutive year. The application of the model for three different scenarios of the European energy system in 2050 shows the influence of flexibilities on the use of PtG storages. In the first scenario, only low flexibility is assumed with mostly heat-driven CHP generation and little demand response. While the third scenario represents high flexibility, the second is placed in between. Results show that the use of long-term PtG storages is highly affected by other flexibility options and thus, system consideration is essential for flexibility evaluation.

3 - Evaluation of Future Power Market Designs in Germany

Fabian Grote, Albert Moser

The European electricity markets are converging due to an increased coupling of electricity markets, grid expansion and rising share of renewable energies in electricity generation. These changes have negative implications for the conventional generation stack, which has led to discussions about a medium and long term sustainable power market design. If today's energy-only market design is considered not sufficient, different options for capacity mechanisms are possible, with different design parameters affecting the profitability of the conventional generation stack. In some countries a decision has already been made, e.g. Great Britain, which has introduced a central capacity auction. In other countries, like Germany, the debate is still ongoing. This contribution presents a linear simulation approach to model the market-based development of the conventional generation stack depending on power market design in order to evaluate the impact of different design options on security of supply. The market-based development is simulated in an iterative two-step approach by firstly determining European

wide power plant dispatch as well as electricity prices and secondly decommissioning and investment decisions based on profitability. Results for a simulation of Germany show that today's energy-only market design does not guarantee security of supply in the medium term whilst capacity markets do but at higher costs.

4 - Modeling and forecasting the residential electricity consumption in Brazil with Pegels exponential smoothing techniques and bottom up approach per end use

Reinaldo Souza, Paula Maçaira, Fernando Luiz Cyrino Oliveira

The importance of the residential class in the consumption of electricity in Brazil can be recognized for, in 2013, concentrates 27% of the total consumption, and being the class that the main public policies such as labeling and increased energy efficiency of appliances are applied. The Energy Research Company (ERC) is in charge of publishing two reports which contain the forecast for longer lead times of the electricity consumption in Brazil. This work aims to model and predict the residential consumption series with two approaches, top down and bottom up. The first uses Pegels exponential smoothing methods and for the second is applied the model FORECAST-Residential, developed by the Fraunhofer Institute, Germany. In addition to model and predict, the top down approach performs an optimization of the model hyper parameters to adjust the projected values with the figures provided by ERC. Due to the bottom up-design, socio-economic drivers, techno-economic characteristics and user behavior can be explicitly modeled. With the second model the forecast of the residential consumption of electricity is calculate as a vintage stock model. The results obtained show that with both approaches, despite all the problems found in data collection for the bottom up case, it is possible to predict satisfactorily the residential electricity consumption up to 2050 and the exercise of optimization proved to be important for providing level and trend equations for the official expectations.

■ MD-15

Monday, 14:30-16:00 - TIC Conference Room 6&7, Level 3

Cutting and Packing 4

Stream: Cutting and Packing
Invited session
Chair: *Xiang Song*

1 - Exact Algorithm for the Two-Dimensional Guillotine Cutting Problem

Krzysztof Fleszar

We propose a new exact algorithm that determines whether a set of rectangular items can be cut from a rectangular bin using guillotine cuts only, with fixed item orientation or with 90-degree item rotation. The algorithm constructs patterns of items by means of horizontal and vertical builds. To speed up the algorithm and reduce its memory requirement, patterns using the same subset of items are grouped together, and dominated patterns are discarded in each group. Moreover, the algorithm tries to prove infeasibility with a subset of items before considering all items. Furthermore, a heuristic capable of completing a partial pattern is repeatedly used during the algorithm in order to determine a feasible solution quickly. Computational experiments on benchmarks from the literature show that our algorithm greatly outperforms previously proposed algorithms for the problem without rotation. Results for the problem with rotation are also reported.

2 - A Matheheuristic Algorithm and an Approach of Granular Tabu Search for the Vehicle Routing Problem with 3-Dimensional Loading Constraints

David Álvarez Martínez, Luis Miguel Escobar Falcón, John Willmer Escobar

This paper presents a matheheuristic algorithm and an approach of granular tabu search for solving the capacitated vehicle routing problem with practical three-dimensional loading constraints. This problem is known as 3L-CVRP (Capacitated Vehicle Routing Problem and Container Loading Problem). The matheheuristic proposed consists of two phases. The first phase uses an optimization procedure based on cuts to obtain solutions of the capacitated vehicle routing problem. The second phase validates the solutions of the first phase by a GRASP algorithm. In particular, the GRASP approach considers the packing

problem for each route. The former algorithm uses a Lagrangean re-laxation of the classical model of two subindex for the vehicle routing problem and different types of cuts (subtour elimination, capacity and packing constrains cuts). The tabu search approach is used in the first phase to replace the branch and cut procedure. This approach uses a granular search space, which is based on the utilization of a sparse graph containing the edges incident to the depots, the edges belonging to the best solutions found so far, and the edges whose cost is smaller than a granularity threshold. The proposed algorithms are compared with the most effective approaches for the 3L-CVRP on benchmark instances considered in the literature. The computational results show that the proposed approaches are able to obtain good solutions, im-proving some of the best-known solutions.

3 - Approaches for the Traveling Salesman Problem with Pickup and Delivery and Two-dimensional Loading Constraints

Thiago Alves de Queiroz, Fabrício Machado, Reinaldo Morabito, Mauricio Resende, Flávio Keidi Miyazawa

The aim of this work is to present a branch-and-cut and a biased random-key genetic algorithms for the Traveling Salesman Problem with Pickup and Delivery where the customers' demand are two-dimensional rectangular items. Real-life applications arise in trans-portation of fragile rectangular shaped items (e.g., furniture and house-hold appliances) and pallet distribution. This problem requests for a minimum Hamiltonian tour where a pickup vertex must be visited prior to its respective delivery vertex, so the rectangular items are arranged in a two-dimensional way (non-overlapping and respecting the vehi-cle surface dimensions), satisfying the sequential order imposed by the tour, and without violate the vehicle weight capacity. We consider an integer formulation solved by a branch-and-cut algorithm, which incorporates valid inequalities on subtour elimination, precedence sat-isfaction, order and loading constraints. The two-dimensional packing problem that emerges is modeled and solved by a constraint program-ming based approach which seeks for feasible packings. Moreover, a biased random-key genetic algorithm, which considers routing and packing operations, is applied to the problem. Computational tests indicate the fast convergence of the approaches on medium-sized in-stances from the literature.

4 - The Multi-Objective Vehicle Routing and Loading with Time Window Constraints

Xiang Song

The multi-objective vehicle routing and loading with time window constraints is a variant of the Capacitated Vehicle Routing problem with Time Windows (CVRPTW) with two/three-dimensional loading constraints, which consists of routing a number of vehicles to serve a set of customers, and determining the best way for loading the goods ordered by the customers on the vehicles used for transportation. The four objective functions pertaining to minimization of total travel dis-tance, number of vehicles to use, total unloading time and the sum of the differences between the workload of each tour and the small-est workload are, more often than not, conflicting. To achieve a range of distinct solutions with no preference knowledge known in advance from the decision maker, a weighted Goal Programming (GP) model was constructed and a Variable Neighborhood Search (VNS) algorithm was designed as the search engine to relieve a computational burden in-herent to the application of the GP model. To evaluate the effectiveness of the VNS algorithm, new sets of instances based on real geographic data and simulated customers' data are generated and solved by both the VAN algorithm and the software provided by our industrial part-ner. Results show that the suggested approach is quite effective, as it provides solutions that are highly competitive with the results found by the software.

■ **MD-16**

Monday, 14:30-16:00 - TIC Conference Room 8, Level 3

Sustainable Design and Operations of Supply Chains

Stream: Sustainable Supply Chains
Invited session
Chair: *Marcus Brandenburg*

1 - Green Investment, Coordination, and Power Structure in the Sustainable Supply Chain

Xiaojun Wang, Xu Chen

In an era of climate change, firms are under increasing pressure to re-duce carbon emissions. It is important for firms to look beyond their organizational boundaries and develop a more holistic solution for an environmental and economic sustainable supply chain. This study ex-amines the role of green technology investment, coordination, and sup-ply chain power structure in achieving this objective. A two echelon supply chain is considered in this study consisting of a manufacturer and a retailer whose customers are price and emission sensitive. Using game-theoretic analysis, we derive the manufacturer's optimal whole-sale price and optimal unit carbon emission, and the retailer's optimal retail price under three supply chain power structures, that are, man-ufacturer Stackelberg, vertical Nash and retailer Stackelberg. In addi-tion, we design a mixed contract that can coordinate the supply chain under different power structures. Finally, through analytically explor-ing potential behavioural changes in a two-echelon supply chain con-text, we discuss the effect of power structure on the two supply chain members' decisions on technology investment, pricing policy, and co-ordination contracts, and the subsequent economic and environmental performances of the manufacturer, the retailer, and the whole supply chain. The findings provide many important managerial insights that can help firms to develop appropriate strategies to reduce carbon emis-sions and sustain market competitiveness.

2 - Modeling Sustainable Supply Chain Management by System Dynamics

Tobias Rebs

Today's globalized economic system involves complex supply chains that require managing environmental and social impacts in alignment with diverse stakeholder expectations for sustainable supply chain management (SSCM). Quantitative modeling approaches for SSCM, particularly analytical and mathematical programming model types, have gained increasing attention, while simulation methods are under-represented. To model complex systems and simulate the dynamics and policy impacts, system dynamics (SD) was developed in a busi-ness management context to reveal the evolution of industrial systems performance. Moreover, SD has proved useful for strategic manage-ment science and operational research. However, the modeling of sustainability-related supply chain performance using SD appears to be rarely focused on by previous research. Thus, this paper provides a review of SD modeling publications in this context and outlines an SD modeling approach for SSCM. A literature review is conducted to identify relevant publications in scientific journals by structured key-word search and defined sample validation criteria. Content analysis is employed to examine the sample papers according to analytic cate-gories deduced from conceptual frameworks. The resulting paper sam-ple comprises forward, but also reverse and closed-loop supply chain models that have to include environmental and social aspects. Infer-ences for future SD modeling in SSCM are drawn and a modeling ap-proach is presented.

3 - Simulation and Optimization to configure Eco-Efficient Supply Shains under Consideration of Per-formance and Risk Aspects

Marcus Brandenburg

Formal models that support multi-criteria decision making represent a strongly growing area in sustainable supply chain management re-search. However, uncertainties and risks in formal models for green supply chain (SC) design are seldom considered. A hybrid simulation and optimization approach is suggested to configure an eco-efficient SC for a new product under consideration of economic and environ-mental risks. Discrete-event simulation is applied to assess the finan-cial, operational and environmental performance and risk of different SC configuration options. The analytic hierarchy process is employed to solve the resulting multi-criteria decision problem of choosing ex-actly one option. The approach is illustrated at a case example of a fast moving consumer goods manufacturer.

4 - Scheduling Workflows in Sustainable Supply Chains Based on Multiagent Systems

Fu-Shiung Hsieh

Global competition, ever shorter product life cycles and pressure from environmental protection are forcing companies to explore more agile and sustainable supply chain practices. Managing workflows in sus-tainable supply chains is a challenging issue due to the computational complexity involved, distributed architecture and dependency among different partners' workflows. Motivated by these needs, this paper aims to study how to achieve agility in sustainable supply chains by exploiting the state of the art information technologies. Our goal is

to develop architecture and a method to endow actors with the ability to configure sustainable supply chain network quickly, flexibly, cost effectively and environmentally responsibly. To achieve our goal, we combine the concept of virtual enterprises (VE), multi-agent system (MAS) architecture, workflow models and optimization theory. The concept VE makes it possible to achieve business objectives through dynamic coalition and sharing of the core competencies and resources in supply chains. A divide and conquer approach is adopted to take advantage of the distributed computation provided by MAS to optimize the workflow schedules in sustainable supply chains. We illustrate the benefits of our approach in cost reduction and just-in-time production by an application scenario.

■ MD-17

Monday, 14:30-16:00 - TIC Conference Room A, Level 9

Strategic Planning and Investment Decisions in Biomass-based Supply Chains

Stream: Biomass-Based Supply Chains
Invited session
Chair: *Magnus Fröhling*

1 - Biomass value chain planning for material and energetic utilization — a capacitated multi-technology, multi-biomass modeling approach

Andreas Rudi, Ann-Kathrin Mueller, Magnus Fröhling, Frank Schultmann

As a response to climate change, policy makers establish legal frameworks to moderate the society's dependency on fossil fuel and mitigate the release of greenhouse gases into the atmosphere by stimulating the application of new material and energy uses of biomass. These new biomass conversion concepts are challenging considering low energy density of biomass, potential direct or indirect food competition and high technology investments. To overcome these challenges and to integrate multiple biomasses and conversion technologies, the design of biomass-based value chains requires decision support. The aim of this research is to provide decision support in the planning of biomass value chains for material and energetic utilization by allocating biomasses from the origin location to capacitated conversion technology facilities whilst maximizing the profit. Whereas most models exclude the technology choice, the developed mixed integer linear program combines location, capacity and transportation planning and technology decisions in one mathematical model formulation. The contribution presents the model formulation, implementation and an example application in the trinational Upper Rhine Region. The application comprises 17 types of biomass, their quantified potentials and 13 conversion technologies, resulting in the identification or upgrading of facilities as well as the biomass-technology allocation for a biomass value chain optimization and its techno-economical evaluation.

2 - Facility location planning for the pre-treatment of forest residues in Chile

Tobias Zimmer, Ann-Kathrin Mueller, Magnus Fröhling, Frank Schultmann

Forest residues are a renewable source of energy that can be used to produce electricity and heat. A challenge hindering the intensified use of forest residues for energy production is the highly dispersed nature of the feedstock and the associated costs of collection and transport to the power plant. This work explores the potential for cost reductions through three different pre-treatment technologies: (1) pelletization, (2) torrefaction combined with pelletization and (3) fast pyrolysis. For this analysis we present a mixed integer linear program (MILP). The MILP represents decisions regarding the optimal number, locations, technologies and capacities of pre-treatment plants and the amounts of feedstock and final products to be transported between the selected locations. It minimizes the objective function of overall costs for the entire supply chain from the recovery of forest residues to the distribution of final products. The model is applied to a case study in four Chilean regions which form the centre of the Chilean forestry industry and feature a high potential of currently unexploited forest residues

that could alleviate the dependency of Chile on imported fossil fuels. The assessment concludes that it is possible to provide forest fuels at delivered costs of about 6 EUR /GJ for torrefied pellets and 9 EUR /GJ for bio-slurry. Scenario and sensitivity analysis indicate that feedstock properties, pre-treatment process parameters and demand are the major cost drivers.

3 - Robust multi-objective optimization of the biofuel sector considering economic, ecologic, and social objectives

Laura Elisabeth Hombach, Grit Walther

In order to ensure supply security as well as targeted emission savings within the transportation sector the usage of fossil fuels must be reduced in the future. In the mid-term, the substitution of fossil fuels by biofuels might help to reach these goals. However, production and usage of biofuels does not only result in positive effects, and trade-offs can be observed between economic (e.g. profit maximization), ecological (e.g. CO_2 minimization), and social (e.g. land use change) objectives. Considering real world problems, uncertainties have to be regarded as well. For instance, fuel demand or technical characteristics of the production plants might be uncertain as well as emissions or future prices/costs of the production network. Against this background, we develop a three-objective, multi-period optimization model, considering cultivation of biomass, production of biofuels, import of biofuels and biomass, as well as blending of fuels. We consider existing uncertainties in the constraints of the model (fuel demand, technical characteristics) as well as in the (multi-)objective functions (emissions, costs). Our aim is to identify robust Pareto-efficient solutions and to derive trade-off relations for political decision makers regarding profit maximization, emission minimization, and land use change minimization. The robust multi-objective optimization model will be applied to the case study of the German (bio)diesel market.

■ MD-18

Monday, 14:30-16:00 - TIC Conference Room B, Level 9

Energy Market Modeling 1: Natural Gas

Stream: Energy Market/System Modeling
Invited session
Chair: *Steven Gabriel*

1 - Access charges on natural gas pipeline networks: are entry-exit pricing systems that efficient?

Florian Perrotton

The European gas market is organized as a zonal system, with a unique virtual trading point per zone, and entry-exit tariffs. Those tariffs must ideally cover the operating costs of TSOs (mainly gas compression costs) and encourage suppliers to use the network efficiently. However, entry-exit tariffs only give aggregated information about the network to suppliers, which do not reflect the costs of the TSO in detail. While this is intended at enhancing liquidity, this decoupling between physical and economic gas flows might reduce the efficiency of the overall gas system. Moreover cost-reflecting entry-exit tariffs are usually defined through static ex-ante analysis which assume invariant nominations from the suppliers. Thus, the ex-post locational incentives provided by those tariffs are never properly assessed. In order to analyze the real efficiency of entry-exit tariffs, we define them as the result of an equilibrium problem between profit-maximizing suppliers that choose gas sources and a cost-minimizing TSO that operates the network to satisfy suppliers' nominations. The equilibrium between the linear problems of the suppliers and the non-linear problem of the TSO is formulated as a MCP. We show on simple examples that cost-recovering entry-exit tariffs lead to a loss of coordination and to an inefficient use of the gas network.

2 - The prisoner's dilemma in gas Cournot models: when endogenizing the level of competition leads to competitive behaviors.

Abada Ibrahim

When modeling imperfect competition, players are separated in two categories: those who exert market power and those who are competitive. The question of letting a player freely choose whether it wants to exert market power or not when it optimizes its utility is not extensively discussed in the literature. We analyze the behavior of two countries competing to supply a market in an imperfect competition.

Each country decides the number of firms it authorizes to sell in the market. The interaction between the firms is of a Nash-Cournot type. Each country optimizes its utility, which is the sum of the profits of its firms. Four kinds of interaction are studied. The first calculates the closed loop Nash equilibrium of the game. The second analyzes the cartel outcome when the countries collude. The third focuses on the open loop Nash equilibrium and the fourth models a Stackelberg interaction. We demonstrate that in the closed loop Nash equilibrium, our setting leads to the prisoner's dilemma: the equilibrium is the most competitive and occurs when both countries authorize all their firms to sell in the market. When countries coordinate the number of firms and Stackelberg cases, the market is on the contrary very concentrated and the countries strongly reduce the number of firms that enter the marke. These results suggest that the prisoner's dilemma outcome is due to the conjectural inconsistency of the Nash equilibrium.

3 - A Rolling Horizon Approach for Mixed Complementarity Modeling with Endogenous Probabilities: Application to Natural Gas Markets
Steven Gabriel, Mel Devine, Seksun Moryadee

In this talk, we present a new approach for solving market equilibrium models using the concept of a rolling horizon. For each roll, a separate mixed complementarity problem (MCP) is solved with decisions from previous rolls fixed for the current one. Each MCP is stochastic and reflects various aspects of the gas supply chain. Such a format is very flexible and allows for example for endogenous probabilities and learning between rolls.

■ MD-24
Monday, 14:30-16:00 - John Anderson JA3.25 Lecture Theatre

MADM Application IV

Stream: MADM Applications
Invited session
Chair: *Huey-Kuo Chen*

1 - A New Model Formulation for the Traffic Assignment Problem Involving Entropy Maximization
Huey-Kuo Chen

In this paper, we propose a two-objective model formulation for the entropy-based traffic assignment problem which includes the maximum entropy user equilibrium (MEUE) problem and the logit-based network loading (LBNL) problem as special cases. The MEUE problem has been formulated as a nonlinear single objective model (Bar-Gera, 2010) in which the user equilibrium conditions are assumed and must be contained in the constraint set. The LBNL problem is particularly addressed here by deriving and discussing the corresponding optimality conditions. A few remarks on uniqueness and proportionality in network loading are also given. For the purpose of demonstration a numerical example for the LBNL is provided and the results thus obtained are deliberately compared with those of MEUE. Largely based on Yen's K shortest loopless paths (Yen, 1971; Chen and Feng, 2010), a solution algorithm for the LBNL is currently under development by the author.

2 - Modeling the technology learning effect on measuring R&D efficiency of IT industries
Li-Ting Yeh, Dong Shang Chang

The effect of technological learning, which results in continuous improvement of investment cost and R&D efficiency of firm over time, has been widely discussed. The cumulative technological learning effect may form as a source of the intellectual capital. Thus far, the data envelopment analysis (DEA) model has not been used to examine the longitudinal technological learning effect. Therefore, a two-stage approach is developed together with the estimation of a latent technological learning effect using time-series data; the estimated technological learning effect is then used as an input in the DEA model. The proposed DEA model will be applied to investigate the technological learning effect of global information technology industry on R&D efficiency evaluation. The result demonstrates that it is relevant to integrate the technological learning effect into the evaluation of R&D efficiency.

3 - Using OCBA and APSO to Efficiently Planning the Order Batching Problem of Order Picking Systems
Ling-Feng Hsieh

The order batching strategy is a key factor for the performance of order picking systems. The combinations of three batching rules (PSOB, PSOB and Associated batching) with two routing rules (Traversal and Optimal routing) are experimented to find the optimal combination. The objectives of this study including make the total order picking distance and total CPU running time minimized, and vehicle capacity utilization maximized. The Optimal Computing Budget Allocation (OCBA) is applied in simulation experiment to reduce the number of simulations and improve simulation efficiency. The PCS value determines the simulation allocation for critical combinations that the total budgeted cost is minimized.

4 - Applying Markov Chain Model to Study Business Operation of Insurance Companies in Taiwan
Cheng-Ru Yang, Yi-Hsien Wang, Fu-Ju Yang, Rui-Lin Tseng, Yi-Hsien Chen

Back to 2008, there was an important event of bankruptcy of Lehman Brothers from issuing low quality mortgage back security. This create a number of following issues which have been affected both global and foreign local financial market and economy including Taiwan. For Taiwan effect, it triggered American International Group (AIG) withdraw more than 95% stake in Nan Shan Life Insurance Company. However, from the event of Nan Shan Life Insurance, the insurance companies rise risk premium but capital gains and operating income of insurance companies is still relatively lower, not covered the higher risk. So, the company must be careful of operations. In this study, we follow the point of view of investors to understand the insurance company's operating condition and make analysis by applying absorbing Markov chain model to estimate transition matrix of different business operation (Anthony and Ramesh, 1992; Daft, 2014) to different life-cycle stages of financial activities during 2009-2013. This study will help investor and managers as reference for decision-making.

5 - Weather Effect on Stock Market Return and Volatility in Taiwan
Je-Wei Jang, Wan-Rung Lin, Yi-Hsien Wang, Ping-Hui Huang, Chih-Hsiung Tseng

Many literatures have shown that weather factor encourage people to engage in a particular behavior, and it also found that three factors which consists of sunshine, temperature and humidity cause the greatest influence on psychological of investors (Howarth and Hoffman, 1984). However, some results indicated that the weather effect were not fairly significant (Trombley, 1997; Ben and Wessel, 2008; Jing and Robin, 2012). Hence, our research will use the weather variables; sunshine, temperature and humidity, to detect the effects of extreme weather factors on stock return. The sample data used in this study consists of the daily stock price of Taiwan from 2009 to 2014. Considering the volatility asymmetric effects, this study used GJR-GARCH model to capture stock market return. In addition, the volatility of the stock market affected by numbers of economic factors. Therefore, this study add the market situation, bear or bull market, to be an additional condition whether it can make the effect of weather more significantly. Finally, the result from this research will support the relative literatures and can be provided as an advice for investors.

■ MD-25
Monday, 14:30-16:00 - John Anderson JA3.14 Lecture Theatre

Single- and Multi-Objective Location Problems

Stream: Continuous Multiobjective Optimization and Robustness
Invited session
Chair: *Christian Günther*

1 - Sum of and Difference between Distances to the First and Second Nearest Facilities
Masashi Miyagawa

This work examines the sum of and difference between the distances to the first and second nearest facilities. The sum of the distances represents the service level of facility location when customers are serviced by the first and second nearest facilities, whereas the difference between the distances represents the reliability of facility location when the nearest facility is closed. The distributions of the sum and difference are derived for regular and random patterns of facilities. Distance is measured as the Euclidean distance. The distributions on a road network are also calculated. The distributions show how the sum and difference are distributed in a study region, and thus are useful for facility location problems with closing of facilities.

2 - Application of Nonconvex Subdifferentials for Solving Semi-Obnoxious Facility Location Problems
Marcus Hillmann

The problem of locating a new facility with simultaneous consideration of existing attraction and repulsion points is a single-objective nonconvex location problem with great practical relevance. We will present a new approach for (approximately) solving such problems using nonconvex subdifferentials. While there are many theoretical results on these subdifferentials, it is rarely possible to explicitly calculate them. We will show that by taking advantage of the special structure of the mentioned problems, it is here for once possible to precisely calculate the corresponding subdifferentials. Furthermore, we will use these results to establish algorithms for solving the semi-obnoxious facility location problem based on different kinds of distance functions. At the end of the talk, we will give an outlook on possible future developments.

3 - Outlier Handling for Center Location Problems - A Multi-Objective Perspective
Teresa Schnepper, Kathrin Klamroth, Justo Puerto

Location models typically use the distances to all customer locations for the assessment of the service provided by new facilities. Particularly when locating central facilities, i.e. when using a center objective function, the optimal new location is sensitive to outliers among the customer locations that are located far away from the majority of customers. We model the exclusion of distant facilities in a center location problem by using k-max functions: Not the maximal, but the k-th largest distance should be minimized, with k 1. These k-max problems are closely related to ordered median problems as a k-max function is a special case of an ordered median function with special choice of the vector of weights. The k-max problem is non-convex in general which makes it difficult to use classical approaches for OMPs. We show that k-max problems on networks can be solved efficiently by enumerating candidate solutions from a finite dominatig set that is independent from the particular value of k. As a consequence, k-max centers can be found for all reasonable values of k at little extra cost as compared to a single solver call, for one fixed value of k. We discuss theoretical properties of k-max location problems in relation to classical center problems and ordered median problems. Finite dominating sets are analyzed for different numbers of new facilities using geometric properties. We also show that the k-max problem for 1 new facility is solvable in polynomial time.

4 - FLO — A Tool for Solving Multi-Objective Location Problems
Christian Günther

Project FLO (Facility Location Optimizer) aims at providing a MATLAB-based tool for solving multi-objective as well as single-objective location problems. We will present algorithms and features of the current version of the Software FLO. The classical single-facility multi-objective location problem consists in minimizing the distances between a new facility and a finite number of given facilities in the plane simultaneously. In this talk, we focus on location problems with uncertainties in the data and present results concerning computing the set of robust efficient solutions for special classes of multi-objective location problems with uncertainties in the data. At the end of the talk, we give an overview of expected future development steps of the Software FLO.

■ MD-26
Monday, 14:30-16:00 - John Anderson JA3.17 Lecture Theatre

Energy-aware Scheduling

Stream: Scheduling with Resource Constraints
Invited session

Chair: *Jan Weglarz*

1 - Power-aware Scheduling of Project Activities with Identical Processing Rates
Grzegorz Waligora

We consider a discrete-continuous project scheduling problem. In such problems activities of a project simultaneously require discrete and continuous resources for their execution. In our problem there are discrete, renewable resources like, e.g., machines, tools, devices, etc., and the number of these resources is arbitrary but fixed. On the other hand, there is one continuous, renewable resource, which is electric power, and the amount of the continuous resource available at a time is limited by 1. Activities are nonpreemptable, and the processing rate of each activity is the same continuous, increasing, and concave function of the amount of power allotted to the activity at a time. The problem is to find a precedence- and discrete resource-feasible schedule and, simultaneously, a continuous resource allocation, that minimize the project duration. We discuss the general methodology for solving the considered problem, which consists in a decomposition into a discrete and a continuous part. We show that under identical processing rates of activities the representation of the solution to the discrete part of the problem can be simplified. The solution of the continuous part requires, in general, solving a nonlinear mathematical programming problem. We describe a genetic algorithm approach to the problem under consideration. Some computational analysis of the proposed GA are presented. Finally, conclusions and directions for future research are pointed out.

2 - Two Heuristics with Opposite Order of Allocation of Machines and Power for Preemptive Jobs and Makespan Minimization
Rafal Rozycki, Jan Weglarz

We consider a laptop scheduling problem where independent and preemptive computational jobs of given size have to be processed on multicore processor. The cores of the processor are driven by a common power/energy source of limited capacity. We consider the makespan as a scheduling criterion. The processing rate of a job depends on an amount of power allotted to this job at a moment. This relation is expressed by an increasing, concave processing rate function. The only known exact method of finding optimal solution of the considered problem requires a complex nonlinear mathematical programming problem to be solved. Unfortunately, the number of variables grows exponentially with the size of a problem instance in such approach. Thus it is justified to construct some effective heuristic approaches. We propose two heuristic algorithms to cope with the considered problem. These algorithms have been examined during an computational experiment.

3 - Energy-efficient Scheduling of Workflow Applications in Computational Grid Environment
Marek Mika

A computational grid is a high performance computing system consisting of computer resources distributed over multiple locations and connected via computer network. Usually, it is developed to execute various types of applications. One type of such applications is known as workflow applications, which consists of multiple computational tasks, which are precedence related, and usually process huge data files. These are very time consuming applications. Thus, it is justified to schedule them before execution in order to optimize a given criterion. In recent years one of the mostly used objectives is the minimization of the energy consumption. Sometimes a good policy for such problems is to execute all the tasks as quickly as possible and then turn off the resources used. A so-called "on/off" model is proposed for this problem. Some resource allocation algorithms are developed for the proposed model of the problem in order to find a set of feasible allocations of resources to tasks. A metaheuristic approach is proposed to find a semi-optimal schedule in the set of feasible solutions obtained in previous step.

4 - Scheduling Orders in an Injection Plant to Minimize Setup Cost.
Joanna Jozefowska, Marek Goslawski, Marcin Kulus, Jenny Nossack

We consider an injection molding plant with unrelated machines. Each item requires the machine to be equipped with a special mold. The setup operation is time consuming. Items are processed in batches. Processing time of an item depends on the machine. The objective is to minimize the total setup time. Mathematical model of the problem is proposed and a heuristic solution is developed and tested in a computational experiment.

■ MD-27

Monday, 14:30-16:00 - John Anderson JA3.27, Level 3

Stochastic Optimization Methods

Stream: Stochastic Optimization
Invited session
Chair: *Silvia Vogel*

1 - Confidence Sets in Multiobjective Optimization
Silvia Vogel

Random approximations of decision problems with one or more objectives come into play if unknown quantities are replaced with estimates or for numerical reasons. Hence there is the need for methods that help to evaluate the goodness of the solution of the approximate problem. We shall derive confidence sets for the sets of efficient points and the corresponding solutions, making use of knowledge about the approximate problems and uniform concentration-of-measure results. The approach can also be employed to develop statistical tests for optimality. Special emphasis will be put to so-called order approximations.

2 - Quantiles in Regression Framework
Jan Amos Visek

The least weighted squares represent the robustified version of the ordinary least squares. The basic idea of the definition of estimator is to assign decreasing weights to the order statistics of squared residuals rather than to the squared residuals directly. In other words, the estimator is the argument (in corresponding space of regression coefficients) which minimizes the sum of products of weights and of order statistics of the squared residuals.

We can reach a higher flexibility of estimator when we consider instead of squared residuals a positive, non-decreasing function of the order statistics of squared residuals. To prove the consistency of new estimator we need a generalized version of Kolmogorov-Smirnov result on convergence of the empirical distribution function to the theoretical underlying distribution, but inverted into the convergence of quantiles. So, the results can be also interpreted as generalization of the classical result on convergence of the order statistics to the corresponding quantiles into the regression framework (where we show uniform convergence in the argument of d. f. but also uniform convergence with respect to the regression coefficients).

■ MD-28

Monday, 14:30-16:00 - John Anderson JA3.26, Level 3

Advances in Continuous Optimization

Stream: Continuous Optimization (contributed)
Contributed session
Chair: *Yaqing Lu*

1 - Entropy-based weighting for multiobjective Optimization
Luiz Celio Souza Rocha, Anderson Paulo Paiva, Pedro Paulo Balestrassi, Paulo Rotela Junior, Edson Pamplona, Marcelo Nunes Fonseca, Giancarlo Aquila, Victor E M Valerio

In practical situations solving a given problem usually calls for the analysis of more than one objective function giving rise to multiobjective optimization. The purpose of multiobjective optimization methods is to offer support to find the best compromise solution. Playing important roles in this are a decision maker and his preference information. In the multiobjective optimization process is the decision maker that, sooner or later, obtains a single solution to be used as the solution to his original multidisciplinary decision-making problem. Hence, a worthwhile research question may be posed thus: In multiobjective optimization, what can facilitate the decision maker in choosing the best weighting? In answering such a query, we propose to use two objectively defined selection criteria: Shannon's Entropy Index and Global Percentage Error. Entropy can be defined as a measure of probabilistic uncertainty. Among the many other desirable properties of Shannon's Entropy Index, we highlight the following: Shannon's measure is non-negative, and its measure is concave. Using Global Percentage Error

we want to evaluate the distance of the determined Pareto optimal solution from its ideal value. The main contributions of this study are the proposal of a structured method of identifying optimal weights for multiobjective problems and the possibility of viewing the optimal result along the Pareto frontier of the problem. This viewing allows more efficient management of processes.

2 - Imitation modelling of process of using resource with limited period of validity
Natalia Stepanova

For effective management of industrial or commercial enterprise using a resource with limited period of validity it is necessary to have reliable appraisals of basic characteristics of casual process of employing this resource. These characteristics include mathematical expectations (average values) and dispersions of the following random values: volume of demands for a resource during production cycle X and time of using a lot of resource t. The result of the work of an enterprise can be achievement of statistical (selective) data of two types: 1) real time of using a lot of resource (if there isn't enough resource), 2) real amount of employed resource (if there is some resource left). Natural conditions of the work of an enterprise taken into account, in each of these cases a regular production cycle is over.The paper examines achievement of statistical estimates for mathematical expectation M(X) and standard deviation on the basis of combined selection of data of the first type and the second type. These estimates are obtained with the help of two methods: method of moments and method of probability. In order to obtain these estimates asymptotic normality of distributing random values X and t was used.On the other hand, since the data of the first type and the second type were obtained under the above-mentioned limiting conditions their direct usage for getting statistical estimates of random values X and t is impossible.

3 - Model and algorithm of a course timetabling problem based on satisfaction with course selection
Yaqing Lu, Kunpeng Li

Course selection and timetabling are important parts of educational administration job. This paper concerns on a course timetabling problem for a whole semester based on course selection due to its complexity as the conflicts between two courses grows rapidly. The objective function is to maximize the students' satisfaction with the result of course selection after timetabling. First, a mathematical description of the problem is made and the appropriate model is established, then the a three phase approach is described to solve the problem: at first, data preprocess is used to calculate the courses conflict matrix and the student course matrix; then a feasible timetable is constructed from the greedy algorithm based on course priority; and finally we try to get a high quality timetable through the neighborhood search algorithm. The results obtained from the proposed algorithm are compared with those of curriculum-based course timetablingshowing that the algorithm proposed in the paper can improve the students' satisfaction with course selection as well as avoid violation of various kinds of constraints.

■ MD-29

Monday, 14:30-16:00 - John Anderson JA4.12, Level 4

Data Analysis for Emerging Applications 4

Stream: Data Analysis for Emerging Applications
Invited session
Chair: *Alexander Aduenko*

1 - Matching Critical Success Factors of Employee Performance to Help the Recruitment Process in Analysing Candidate Profiles by Incorporating Social Media Analytics
Ryzky Yudha

Employee performance is managed through Key Performance Indicators (KPIs) that vary across organisational focus and employee's function. In the meantime, professional recruiters accept candidates through job descriptions gathered from the manager's view of a specific role. This can be easily biased by his/her expertise and experience. The first part of this study proposes an analytical procedure to identify success factors of employee performance.

To link it to the next step of recruitment, in the second part of the study, the identified employee's success factors will be used in candidate assessment. Current procedures for recruitment incorporate interviews

to understand candidate fit to the vacant position. In this study, candidates' social media behaviour analysis is proposed to fulfil this objective. Using a social media analytics approach, the candidate's social media profiles and activities will be structured and matched to the specific role's critical success factors. A match score will help recruiters in making further decisions.

This work is trying to link personal interest captured from social media activities to career objectives. The model provided is expected to help organisations with large numbers of applications to have a deeper view of its potential candidates.

2 - Predicting churn by building a B2B network
Julie Moeyersoms, Vincent Vercruyssen, David Martens

The use of social network data has often proved extremely valuable for marketing purposes in a retail setting. Previous research on this topic has shown tremendous improvements in a variety of applications in terms of predictive performance compared to traditional approaches where only individual customer data are used. Although social network analysis has been successfully applied in a retail setting, the use thereof in a B2B setting is still largely missing.

In this work, we build churn prediction models that incorporate connections between companies, where connections are defined by jointly having the same member in their respective board of directors. The dataset stems from one of the largest energy companies in Belgium to which we added information on the members of the board of directors as well as other financial measures for each company. Firstly, we visually show that there is indeed connectivity (in terms of common members in the board of directors) between the churning companies, indicating that churn decisions of companies might indeed be impacted by the board of directors. Secondly, through the application of network learning algorithms we empirically demonstrate that adding this networked data to the model with traditional data indeed improves the predictive power of the churn prediction model substantially.

3 - Unsupervised sentiment driven university ranking
Andrey Kateshov, Alexander Grigoriev, Nalan Baştürk, Jean-Pierre Urbain

Internet discussion forums are useful sources of knowledge on various subjects. However, an automated extraction of this knowledge is considered to be a relatively difficult task. Yet some pieces of information, for instance the frequency of appearance of a particular name in the forum, are easy to obtain. In this study we use a popular forum dedicated to U.S. universities' admission and selection. We look at universities' monthly frequencies of appearances in the forum and analyze these frequencies in a time series context. We answer the question of how these frequencies and their changes can be interpreted and compared with standard university rankings published annually. In particular, we hardly find an evidence suggesting a direct influence of the well known published university rankings on the university names' frequencies. We also discuss various ways of how such an influence can be measured.

■ MD-30

Monday, 14:30-16:00 - John Anderson JA5.02, Level 5

Scheduling Theory and Support

Stream: Scheduling Theory and Applications
Contributed session
Chair: *Tim Nonner*

1 - Towards a proof of the Coffman-Sethi conjecture
Peruvemba Sundaram Ravi, Levent Tuncel

A schedule that minimizes the mean flow time of a set of n independent jobs on m identical machines is termed a flowtime-optimal schedule. The problem of minimizing the makespan over the class of all flowtime-optimal schedules is known to be an NP-hard problem. In 1976, Coffman and Sethi proposed a simple extension of LPT list scheduling, termed the LD algorithm, for this problem. They conjectured that the LD algorithm has a worst-case performance bound of (5m-2)/(4m-1). We report significant progress in an attempt to prove this conjecture.

2 - Optimal staff allocation for local police force
Hanjing Zhang, Jiyin Liu, Sarah Dunnett, Antuela Tako

Due to the squeeze on public expenditure, local police forces have been faced to cut their budgets since 2010. These reductions provide a great impetus for investigations on more effective allocation of staff, especially the patrol officers in the immediate response service system. Patrol officer workforce management is a complex and serious problem because poor staffing has substantial impacts on operations cost, service quality and public safety. It is often seen as a process consisting of three sequential phases which are identification of demand for staff, staff roster scheduling and roster assignment. This project details the complexities and constraints of the patrol officers' work pattern. The aim is to provide a general framework for workforce management in the service system. Queuing theory as the theoretical basis is applied for the system initialisation. Discrete optimisation via simulation is incorporated to guide the improvement of the stochastic system performance, especially to determine the staff levels based on the numbers of incidents requiring immediate responses. A branch and price algorithm is proposed to generate high quality rosters which not only meet the demand for the patrol officers but also take the officers' working preferences into account. The trade-off among system performance, staff availability and roster quality will be discussed based on the experimental results.

3 - pyschedule - a Python Package to Formulate and Solve Resource-Constrained Scheduling Problems
Tim Nonner

We present pyschedule, a light-weight open source python package to formulate and solve resource-contrained scheduling problems. There are basically two options to address such problems with the help of standard solvers, either the use of an algebraic description language such as OPL, AMPL or GAMS, or by directly utilizing some API for a high-level language such as C++ or Java. The former option offers the advantage of a readable and mathematical concise model description but is quite limited with respect to flow-control, pre-, and post-processing. Therefore, an embedding into a general programming language is often required to add this functionality. On the other hand, the latter option does not provide a readable model description, but offers the advantages of such a general programming environment with all its benefits. Our new package pyschedule aims to find a trade-off by allowing an intuitive and concise formulation of scheduling problems via exploiting language characteristics such as dynamic typing, operator overloading and set/list comprehension while being part of the full-fledged scripting language python.

4 - Project crashing with rewarding early completion and random activity durations
Mohammad AlDurgam

Different objectives may be considered while scheduling a project such as: minimizing project duration, maximizing net profit, or both. Motivated by the practical scenario of a contractor receiving bonus proportional to the earliness of project completion time and penalty for lateness, crashing of project activities can be an option, however, crashing is costly as well, hence, a trade-off between crashing cost and the possible profit/penalty of completing the project early/late is needed. A model which determines the optimal crashing levels of project activities assuming random activity durations is proposed. Due to complexity of the problem, a Monte Carlo simulation optimization solution is suggested and an illustrative example is provided using Arena simulation software.

■ MD-31

Monday, 14:30-16:00 - John Anderson JA5.04, Level 5

Stochastic Modeling and Simulation 4

Stream: Stochastic Modeling and Simulation in Engineering, Management and Science
Invited session
Chair: *Erik Kropat*
Chair: *Zeev (Vladimir) Volkovich*

1 - Optimizing parcel transshipment terminals by combining mathematical optimization and simulation
Jens Baudach, Daniel Diekmann, Moritz Pöting, Uwe Clausen

Mathematical optimization and simulation represent two powerful methods. However, they are mainly applied separately for different types of problems. The (discrete-event) simulation allows the modelling of logistics systems with almost unlimited complexity (including stochastic processes) very close to reality. But finding the best system configuration is very difficult and time-consuming since there are many alternative scenarios that have to be evaluated. In contrast, mathematical optimization has the ability to make complex decisions and find (near) optimal solutions. But real world logistic systems can only be solved on a less detailed level without stochastic behaviour. We present a new solution approach for the tactical-operational planning of parcel transshipment terminals. Our approach closely links the two methods optimization and simulation in order to make use of their complementary advantages. Thus, we are able to handle a large number of decisions, such as (un)loading dock and sorting destination assignments, and consider complex automatic sorting systems as well as manual handling activities with many stochastic elements. In particular, we will discuss several objective functions (e.g. workload balancing, make span minimization) and the feedback step between simulation and optimization. Computational results are presented for different system load scenarios and parcel transshipment terminals, using Cplex (optimization) and Enterprise Dynamics (simulation).

2 - Gate assignment in LTL terminals using a stochastic matheuristic
Lars Eufinger, Uwe Clausen

Freight forwarding companies in the less-than-truckload (LTL) industry are trying to gain a competitive advantage by systematically optimizing the processes and the implementation of logistics innovations. We want to investigate LTL terminals which are the hubs of the LTL transportation networks and operate as distribution centers with the collection and distribution function of goods, e.g. cross docking. The performance of a LTL terminal is largely determined by the proper use of the gates. A gate assignment plan should minimize the waiting times of the trucks while having short transportation distances for the goods inside the terminal. However, many uncertain factors influence the planning. Especially fluctuations in the arrival times of vehicles have great impact on the planning process. Thus it is reasonable to use stochastic optimization to create a gate assignment plan which can handle the occurring uncertainties. We present our stochastic optimization model for the assignment of the trucks to the gates, taking into account the processes inside the terminal, e.g. the movements of the goods from gate to gate. The movement of the goods can be modeled by forklift trucks or by using a conveyor system. In addition to this, we present our matheuristic solution method of the optimization model, which is based on a scenario decomposition approach using 2-stage-stochastic optimization and first computational results.

3 - Smart Cross-training: A Two-Stage Stochastic Program for Training in the Face of Uncertain Demand
Emma Ross, Stein W. Wallace

Cross-training is a popular staffing policy for coping with demand uncertainty and shortage in supply. Implementation of such a policy requires decisions to be made on the number of workers to train, which skills to train them in and to what level. A natural consideration is then whether there are training configurations which lead to a higher level of flexibility than others. Existing cross-training literature is primarily focussed on setting optimal staffing levels for pre-defined training configurations so that the benefits of those configurations can be assessed and compared. These approaches have two key limitations. Inference is limited to a small set of pre-defined configurations - typically variations on the popular block and chain training structures. Further, though useful for establishing a new workforce from scratch, the more frequently faced problem of 'how should our existing workforce be enhanced through training, given what we know (and don't know) about the demand we face?' is not addressed. In this paper, we attempt to better understand the interaction between uncertain demand and cross-training by modelling this training and allocation problem as a two-stage stochastic program. By modelling training as a decision variable we are able see how the optimal configuration responds to characteristics of uncertain demand and summarise those interactions with "rules of thumb' for training.

4 - Systemic Risk analysis
Rosella Giacometti, Gianluca Farina, Maria Elena De Giuli

The aim of this paper is to provide a model for systemic risk attribution in order to disentangle the common EU component parts from the specific ones. Systemic default risk is the risk of simultaneous default of multiple institutions. This risk has caused great concern in recent past, however its measure is not a trivial subject. Following [1], we introduce a multivariate copula for all the countries in EU zone, providing an integrated analysis of the EU Zone. We consider a Multivariate Generalized Marshall-Olkin, where the marginal probability of default of each country depends on its intensity. Using market data of sovereign CDSs and Banks CDSs we calibrate the model. Finally using this specification we perform the risk attribution.

■ MD-32
Monday, 14:30-16:00 - John Anderson JA5.05, Level 5

AHP/ANP 04

Stream: Analytic Hierarchy/Network Process
Invited session
Chair: *Natawat Jatuphatwarodom*

1 - The Effects of Technology Information Services on Distribution Center Customer Satisfaction
Kuochung Chang

This study investigated the effects of technology information service on customer satisfaction of distribution centers in Taiwan. The filed survey included several distribution centers and their respective key customers. Although technical support, information supply, and quick response, three information service functions, are helpful to achieve the objectives of relationship strategies, different perception of empowering between distribution center and their customers was discovered. We employed the analytic hierarchy process (AHP) to resolve the priorities of information service functions effects on the distribution centers' customer satisfaction. Based on the research findings, four suggestions have been given. They are upgrading information service ability, setting up service priority, establishing professional image, and strengthening flexibility and empowering.

2 - A Hybrid Multiple Criteria Group Decision-Making Approach for Green Supplier Selection in the TFT-LCD Industry
Ue-Pyng Wen, Che-Wei Tsui

The awareness of the need for environmental protection is increasing throughout the world. The focuses of green supplier selection are on considering environmental criteria and strengthening the competitiveness of the entire supply chain. The purpose of this study is to develop a green supplier selection procedure for the thin film transistor liquid crystal display (TFT-LCD) industry using polarizer suppliers as an example. First, a decision framework for green supplier selection is developed based on literatures and the supplier audit forms provided by an anonymous flat panel display manufacturer in Taiwan. Then, a hybrid multiple criteria group decision-making (MCGDM) method is proposed based on analytic hierarchy process (AHP), entropy, elimination and choice expressing the reality III (ELECTRE III) and the linear assignment method to assist the manufacturer in choosing among four polarizer suppliers. The final ranking results for green supplier selection and different opinions from each department are provided. An improvement report is suggested to enhance suppliers' performance. For the evaluation procedure, most managers emphasize the importance of current capability and the capability of research and development. Furthermore, we found that the subsidiary supplier should improve quality control competence immediately to be considered as the potential candidate of primary supplier.

3 - A Hybrid Approach for Supplier Selection based on Revised Data Envelopment Analytic Hierarchy Process
Sanjeet Singh, Remica Aggarwal

For most managers, purchasing decisions are key decisions in the achievement of business organization's strategic objectives. Thus, supplier selection is a vital component for every business organization. Supplier selection fulfils these important objectives of the organization by maximizing overall value to the purchaser, reducing uncertainty in supply, and by forming a long term, reliable relationship between buyers and suppliers. Supplier selection is a multi criteria decision making problem which is affected by several conflicting factors. Many

approaches have been proposed for supplier selection, such as the analytic hierarchy process (AHP), data envelopment analysis (DEA), data envelopment analytic hierarchy process (DEAHP). DEAHP approach has been widely used for supplier selection. In this approach, DEA is embedded into AHP. However, this approach suffers from serious drawbacks as it uses counter intuitive priority vectors for inconsistent pair wise comparison matrices and also at times, it generate illogical weights for consistent pair wise comparison matrices as well. We have used revised DEAHP (RDEAHP) approach for supplier selection to overcome these drawbacks of DEAHP. A case study from a well-known automobile manufacturing company is utilized to show the efficiency of the RDEAHP for supplier selection. The uniqueness of our research lies in the application of RDEAHP approach for supplier selection and to the best of our knowledge, this is first such attempt.

4 - A Mixed Modelling Analysis for Supporting Inventory Management and Supplier Selection Decisions in the Thai Silk Industry
Natawat Jatuphatwarodom

The Thailand Textile Institute indicates that there has been a consistent growth in the silk based product industry. The Thai Ministry of Agriculture and Cooperatives however has identified constraints that limit the expansion of Thailand's silk product sector. This research is aimed at developing supplier selection and inventory management optimisation models that support policy decisions of the Thai silk manufacturers' key decision makers. The constraints that restrict the expansion of the silk industry are analysed. The key constraints are identified as product problems, inventory management problems, management problems, marketing problems, and supply chain problems. Supplier selection and Inventory management are selected to be the focal studies. Case studies are developed based on eight representative Thai silk manufacturers. Operational Research models such as AHP,DEA, and GP are applied to suggest improvements in the decision making process of suppliers and inventory management. This will contribute to the best practice framework that can be used to positively impact the Thai silk industry further, depending on the Thai government and key decision makers' requirements.

■ MD-33
Monday, 14:30-16:00 - John Anderson JA5.06, Level 5

Topics in Mathematical Programming

Stream: Mathematical Programming
Invited session
Chair: *Goran Lesaja*

1 - Linearly constrained, separable concave minimization problems: sufficient optimality criteria and algorithm
Tibor Illés

Sufficient optimality criteria for linearly constrained, concave minimization problems is given in this paper. Our optimality criteria is based on the sensitivity analysis of the relaxed linear programming problem. Our main result is similar to that of Phillips and Rosen (1993), however our proofs are simpler and constructive. Phillips and Rosen (1993) in their paper derived sufficient optimality criteria for a slightly different, linearly constrained, concave minimization problem using exponentially many linear programming problems. We introduced special test points and using these, for several cases, we are able to show the optimality of the current basic solution. The sufficient optimality criteria, described in this paper, can be used as a stopping criteria for branch and bound algorithms developed for linearly constrained, concave minimization problems.

2 - Constrained Trace-optimization of Polynomials in Freely Noncommuting Variables
Janez Povh, *Igor Klep*

The study of matrix inequalities in a dimension-free setting is in the realm of free real algebraic geometry (RAG). In this paper we investigate constrained trace and eigenvalue optimization of noncommutative polynomials. We present Lasserre's relaxation scheme for trace optimization based on semidefinite programming (SDP) and demonstrate its convergence properties. Finite convergence of this relaxation

scheme is governed by flatness, i.e., a rank-preserving property for associated dual SDPs. If flatness is observed, then optimizers can be extracted using the Gelfand-Naimark-Segal construction and the Artin-Wedderburn theory verifying exactness of the relaxation. To enforce flatness we employ a noncommutative version of the randomization technique championed by Nie. The implementation of these procedures in our computer algebra system NCSOStools is presented and several examples are given to illustrate our results.

3 - An Improved Infeasible Full Nesterov-Todd Interior-Point Algorithm for the Linear Complementarity Problem over Symmetric Cones
Goran Lesaja

In this talk an infeasible full Nesterov-Todd step interior-point method for Linear Complementarity Problems over Symmetric Cones is considered. Using several new results from Euclidean Jordan algebras and associated symmetric cones, a sharper quadratic convergence result than previously known is established, leading to a wider quadratic convergence neighborhood of the central path for the feasibility steps of the algorithm. However, the best iteration bounds known for the infeasible short-step methods, is still achieved.

■ MD-34
Monday, 14:30-16:00 - John Anderson JA5.07, Level 5

Realistic Production Scheduling 1

Stream: Realistic Production Scheduling
Invited session
Chair: *Ruben Ruiz*

1 - Heuristics for the Unrelated Parallel Machine Scheduling Problem with Additional Resources
Eva Vallada, *M[a] Fulgencia Villa*

In this work, heuristics based on different rules are proposed for the unrelated parallel machine scheduling problem with additional resources and the objective to minimise the maximum completion time or makespan. Both, processing times and resource consumption are machine dependent. A benchmark of instances is also proposed considering small and large instances as well as different ways to generate the processing times and the resource consumption: uniform and correlated distributions. An exhaustive experimental evaluation is carried out using the proposed benchmark, results are analysed by means of statistical analysis in order to identify which methods show the best performance.

2 - Local Search Procedures for Hybrid Flowshop Scheduling Problems with Due Date Windows
Ruben Ruiz, *Quan-Ke Pan*

Due dates are in reality more intervals than specific points in time. We study hybrid flowshops where jobs, when completed inside a due window, are considered on time. The objective is the minimization of the weighted earliness and tardiness from the due window. This objective has seldom been studied and there are almost no previous works for hybrid flowshops. We present methods based on the simple concepts of iterated greedy and iterated local search. We introduce some novel operators and characteristics, like an optimal idle time insertion procedure and a two stage local search where, in the second stage, a limited local search on a exact representation is carried out. We also present a comprehensive computational campaign, including the reimplementation and comparison of 9 competing procedures. A thorough evaluation of all methods with more than 3000 instances shows that our presented approaches yield superior results by a large margin which are also demonstrated to be statistically significant. Experiments also show the contribution of the new operators in the presented methods.

3 - Lot Sizing and Scheduling Problem: A Case Study in the Automotive Industry
Neslihan Gezer, *Fulya Kadi*, *Sercan Eminoglu*, *Tulin Inkaya*, *Betul Yagmahan*, *Evren Geçgil*

In this study, we consider the lot sizing and scheduling problem for the press machines in an automotive company. Each product has a set of eligible machines, and a set of preferred machines, that produce high

quality products. The aim is to determine the amount of production lots and sequence on each machine in a finite planning horizon. The objective is the minimization of total costs, i.e. holding, setup, and machine preference costs. We formulate the problem as the capacitated lot-sizing and parallel machine scheduling problem with setup times, and propose a mixed integer programming (MIP) model. A heuristic approach is developed in order to solve the problem in a reasonable time. The numerical experiments demonstrate the applicability of the proposed approach to the real life problem.

4 - A Mixed Integer Programming Model for a Tile Scheduling Problem
Carina Pimentel, Armindo Soares

In this work a mixed integer programming model is presented for a scheduling problem from a tile industry. The company produces ceramic materials, namely paving and coating tiles, of several types, patterns, colours and sizes. The work that will be presented is related to the integrated scheduling of a set of glaze lines and furnaces. The problem can in general be characterized by the existence of a set of parallel glaze lines and a set of furnaces, being the production process performed on the glaze lines and subsequently on the furnaces. In addition, there are huge family setups as well as some incompatibilities between the glaze lines and the products. The furnaces are the bottleneck of the system having a given capacity that must be met (lower an upper capacity limits). The aim is to develop a biweekly scheduling plan that minimizes the production lead time. To do so, a mixed integer programming model that considers all the aspects above mentioned was devised.

■ MD-35
Monday, 14:30-16:00 - Colville C429, Level 4

DEA applications: banking

Stream: DEA and Performance Measurement
Invited session
Chair: *Vania Sena*

1 - Efficiency Evaluation of Banks with Data Envelopment Analysis (DEA) and Production Trade-Offs
Shamaila Ishaq

A growing body of empirical literature has used DEA for evaluating the efficiency of banking sector since 1985. However, standard DEA models often do not provide sufficient discrimination between the efficiency scores of banks particularly, in case of small sample size. Moreover, sometimes additional information is available about different banking operations that need to be incorporated in the evaluation process. Integration of such additional information into DEA model is important for efficiency assessment because in the absence of such additional information, efficiency is generally overestimated. In this paper a novel methodological application of production trade-offs has been proposed for the efficiency measurement of the banking sector. This novel methodology provides a different way of incorporating additional information by developing relationships between inputs and outputs. This proposed development enriches the existing DEA model with the additional information that not only leads to the expansion of production possibility set (PPS) but also provides better accuracy and improved discrimination as compared to standard DEA models. For the empirical application of production trade-offs, realistic trade-offs have been identified in banking operations and incorporated in standard DEA model. Efficiency scores of banking sector so obtained provide improved discrimination between efficiency scores as compared to the efficiency scores obtained with standard DEA model.

2 - The Study of Meta-Frontier Cost Malmquist Productivity Gap Index:An Application of Technical Convergence Effect of the Banking Industry in the US, China and Taiwan
Yung-Lieh Yang, Tzu-Chun Sheng, Chen-Ming Chen, Te-Ke Mai

Based on the convergence hypothesis in Neoclassical Growth theory, this study applied the concept of Meta-frontier developed by Battese and Rao(2002).The method of the decomposition of cost Malmquist productivity index developed by Maniadakis and Thanassoulis (2004)

is reconstructed to establish the Meta-CM-Productivity Gap Index (Meta-CM-PG). The main purpose is to capture the technical convergence effect of the banking industry in the US, China and Taiwan. The empirical results show that the banks in Taiwan have better meta-frontier cost efficiency that the banks in US and China. The better productivity convergence effect exists in the US banks, and converge on Meta cost frontier 4.3 percent each year. However, the better technical convergence effect exists in the Taiwan's banks, and converge on Meta cost frontier 7.2 percent each year. Technical convergence effect is decreased in the banking industry in the US, China and Taiwan.

3 - Bank reforms, ownership, and efficiency in Chinese banking: Further evidence based on a stochastic metafrontier cost function
Chi-Chuan Lee

The efficiency measurement of banking industries is of great concern because of the process of deregulation, globalization, the increased competition and operating risk. This paper compares the cost efficiency of Chinese banking industries with different ownership structure under different conditions of bank reforms using the newly metafrontier approach for the period 1999-2013. Unlike Battese et al. (2004) and O'Donnell et al. (2008), who propose mathematical programming techniques, the stochastic metafrontier is formulated to gauge the technology gap ratio (TGR) in the context of stochastic frontier framework, which is developed by Huang et al. (2014) and can be estimated by econometric method. One salient feature of our method is that the TGR can be further specified as a function of some exogenous variables that reflect group-specific environmental differences, while the programming techniques are not allowed to do so. Empirical results show that both TGR and metafrontier cost efficiency (MCE) are underestimated by programming techniques. The average TGRs in these countries are close to one another, implying that banks operating in this integrated market undertake analogous technology. Moreover, the TGR and MCE exhibit a gradual upward trend during 1999-2006, followed by a downward trend especially after the subprime crisis of 2007-2013. The managerial inability constitutes the primary source of inefficiencies, since the CE component is found to be lower than the TGR.

4 - Trademark strategies and entry mode: an analysis for the Europe commercial banks
Vania Sena

The purpose of this paper is to understand how banks in Europe use trademarks when entering into foreign markets. We identify a set of trademark strategies followed by a sample of European banks between 2008 and 2013 and link their choices to the entry mode into foreign markets. DEA is used to assess the impact on the performance of banks of the use of these specific strategies.

■ MD-36
Monday, 14:30-16:00 - Colville C430, Level 4

OR Promotion among Academia, Businesses, Governments, etc. 2

Stream: Initiatives for OR Education
Invited session
Chair: *Kseniia Ilchenko*
Chair: *Yuliia Puzanova*

1 - OR Promotion among UN, Universities Enterprises, etc.
Erwin Reizes

In this lecture, methods and experience will be presented in using and promoting OR among University-planning, University-Industry system design, National Productivity Center foundation and administration, Enterprise counseling, as Professor and head of OR department, UNESCO CTA, ILO expert, Adviser, Industrial Eng., in Uruguay, France-Spain, Cuba, Venezuela, Ecuador and Nigeria, since 1962. The background of the System and Administration theory has been mentioned in Vilnius 1012 and Barcelona 2014.

2 - Bias in Customer Satisfaction Scores
Andrew Brint

The online rating of experiences is extremely pervasive ranging from books on Amazon through to academics on RateMyTeachers. While the information provided greatly assists the ordinary members of the public in making decisions, there are many widely reported problems that arise from the unregulated nature of the contributions. Perhaps the most obvious problem is that respondents are not a random sample from the population. However, there are other potential issues with using customer satisfaction scores. This talk considers whether different sections of the population give significantly different average scores from other sections of the population. Folklore has traditionally suggested that some nationalities have more extreme responses than others, that satisfaction with the service received changes with age and different social strata complain more than others. If these suggestions were true, then it would be a problem for situations where organisations are punished or rewarded based on their customer satisfaction levels. For example, a regional "public sector company' might have its satisfaction score lowered simply because of its catchment area leading to the potential regulatory fines for poor performance. This talk reports on research that was carried out to see whether (and if so how) region, age and gender affect the average customer satisfaction rating.

3 - O.R. in Schools: Helping Young People to Make Better Decisions
Charlene Timewell

O.R. in Schools (ORiS) is one of The OR Society's key strategic projects, which promotes Operational Research to young people and their teachers in a bid to fulfil the Society's vision that "every school child knows what O.R. is'. Join The OR Society's Education Officer to explore how the ORiS initiative broadens young people's horizons by demonstrating exciting, real world applications and possible careers using some of the mathematics they're learning in the classroom. Celebrate the successful, yet challenging journey that the ORiS initiative has made so far, including sharing a wealth of O.R. information and teaching resources, maintaining a Student Ambassador Project, and forging and sustaining connections with educational institutions across the UK. Enjoy an insight into the future plans for ORiS, particularly in light of the UK mathematics curriculum reforms. Find out why O.R. practitioners are fundamentally vital to the success of ORiS and how to get involved with the initiative in your local area.

■ **MD-37**

Monday, 14:30-16:00 - Colville C411, Level 4

Optimization for Sustainable Development 4

Stream: Optimization for Sustainable Development
Invited session
Chair: *Sadia Samar Ali*

1 - Multiobjective Optimal Design of Ecological Networks. The Case of Medellin, Colombia
Laura Lotero, *Patricia Jaramillo*, *Luis-Anibal Vélez*

Socioeconomic development and urban growth has fragmented the territory and has affected the free movement of animal species. The creation of ecological networks to connect the forest fragments through vegetation corridors, improves the coverage of these fragments in terms of permeability for the movement of species. Literature has focused on analyzing the existing ecological networks and assessing them in terms of connectivity indexes, but little attention has been put on designing an optimal ecological network from a multiobjective perspective.

In this work, we present a binary optimization model considering multiple objectives, taking into account ecological and economic interests. We also include some desirable indicators from complex network theory to assess connectivity and the quality of the network from a complexity science view. We apply our model to a natural reserve area next to Medellin (Colombia) consisting of 18 forest fragments in order to create an optimal ecological network for bird species. We make use of the advantages of Geographic Information Systems and mathematical programming to model and solve the multiobjective problem. Our results are Pareto optimal and robust. Our model can be extended as an ecological strategy for the management of urban sprawl in developing cities in a sustainable way.

2 - Deploying optimization fast or for long ? Why not both ?
Alex Fleischer

Most of us in the OR community like discussing ideas and we like trying new ways. Which means testing as fast as we can. (Faster than others that could get the same ideas even faster)

But being succesful in OR is also about building a model that will run for 10 years or more.

We'll discuss how to find the right compromise, tell stories but without giving any names.

We'll give examples around IBM ILOG optimization and CPLEX.

3 - Multi-Objective Celluar Production Design and Solution Approaches: An Application in A Public Corporation
Necati Konyalı, *Mustafa Kocabaş*, *Ömer Biyikli*, *Ilhan Atik*

Cellular Manufacturing is an application type of Group Technology and constitutes the technological basis for "flexible manufacturing systems" and "computer integrated production". Cellular manufacturing is an approach that tries to produce diverse products as soon as possible and at minimal costs. Cellular manufacturing design is a spreadingly used technique in systems where significant part families are processed. In this study, it was intended to have a cellular manufacturing design formed by machines and parts thereof in Air Supply and Maintenance Center Manufacturing Workshop. A multi-purpose mathematical model was developed suitable for the structure and purposes of the study. In the problem, two objectives conflicting with each other were discussed. While one of them is to minimize the number of process (cell spaces) not assigned into the cell, the other is to maximize intracellular capacity utilization. As the established model is multi-purpose, multi-objective decision-making techniques were solved using GAMS program, and the results were compared for each. Multi-purpose decision-making techniques used in the study are Goal Programming, Weighted Total Scalarization Method, Epsilon Constraint Scalarization Method, Hybrid Scalarization Method, and Benson Scalarization Method. Interpreting the results obtained by multi-objective decision-making techniques, the study was completed.

4 - A mathematical model for scheduling preventive maintenance and renewal projects of infrastructures with application to a case study on railway tracks
Farzad Pargar, *Rob Basten*, *Matthieu van der Heijden*, *Leo van Dongen*

We introduce the preventive maintenance and renewal scheduling problem for a multi-unit system over a finite and discretized time horizon. Given the latest possible time for carrying out the next maintenance and renewal projects after the previous ones and considering several common setup costs, the introduced scheduling model minimizes the costs of projects by grouping them and simultaneously finding the optimal balance between doing maintenance and renewal. We present a 0-1 pure integer linear programming that determines which projects to perform together on which location and in which period. We consider railway tracks in a case study and test the performance of the proposed model on a set of problem instances. The experimental results show that the proposed approach performs well.

■ **MD-38**

Monday, 14:30-16:00 - Colville C410, Level 4

Humanitarian Applications 5

Stream: Humanitarian Applications
Invited session
Chair: *Reza Zanjirani Farahani*

1 - Should EMS Managers frequently move their ambulances to meet the demand?
Hari Rajagopalan, *Cem Saydam*, *Elizabeth Sharer*, *Marie DeVincenzo*

Demand for ambulances is known to fluctuate spatially and temporally by day of the week, and time of day. Faced with fluctuating demand during the day, EMS managers have the option of redeploying their fleet to compensate for such varying demand. Recent reports suggest that EMS managers are aware of the benefits and drawbacks of redeployments. Such shifting of personnel, while better able to cover a region with fluctuating demand, can cause fatigue amongst ambulance crew members. We compare and contrast two models (1) The Dynamic Available Location Problem (DALP) and (2) Dynamic Redeployment Location Problem (DRLP) using a trace driven simulation model. The DALP focuses on minimizing the number of ambulances allowing redeployments while the DRLP minimizes the number of ambulances as well as the number of redeployments. We present comparative statistics using real data from an urban EMS agency.

2 - Are extreme events truly random and unpredictable?
Reza Zanjirani Farahani, Hoda Davarzani, Martin Starr, Sushil Gupta

Modelling the humanitarian operations management (OM) decisions involves incorporating parameter uncertainty. Are extreme events as unpredictable as we have been led to believe? In modelling the extreme events, researchers mainly presume popular probability density functions (PDFs) for timing and magnitude of disasters (e.g. Poisson and uniform) which permits less calculation effort. This research aims at testing validity of such assumptions and their significance on humanitarian OM decision making. An empirical study based on historical data and statistical analyses of natural disasters is conducted to investigate fitness of different PDFs. In both state-wide and nation-wide pilot studies, we observed the appropriate PDFs for the time between two consecutive events and also the number of fatalities in each event may follow other PDFs such as Weibull, Gumbel and Frechet; uniform distribution may also be applicable. In order to investigate importance of considering appropriate PDF, a rudimentary pre-positioning inventory model is used to determine range of errors for adapting an inappropriate PDF. A warehouse, which is designed to accommodate sudden-onset disasters, using a continuous review (s, S) system with one perishable item is modelled. Significance of cost and consequences of considering various PDFs are tested. The study so far is limited by sample size and scope of database. Although the results may not be generalized, the research methodology is evident.

3 - Improved Triaging and Resource Management in Emergency Departments
Kum-Khiong Yang

Long waiting times in emergency departments (EDs) not only affect patients' perceived quality of care, but also increase crowding which can adversely affect patients' outcomes. The entire length of stay in an ED (EDLOS) has been found to affect patients' outcomes and demonstrated to be closely associated with delays in the provision of ancillary services to ED patients who requires such services from diagnostic and testing laboratories.

The focus of this study is to improve the flow of ED patients by testing alternative triage processes, laboratory setups, and capacity of physicians, triage nurses and laboratories. Three alternative triage processes and the use of shared versus dedicated laboratories are compared across different utilization of physicians, triage nurses, and laboratories using a discrete event simulation (DES) model that captures the pertinent characteristics of EDs operating in large tertiary acute care hospitals under conservative assumptions.

Our results show that these factors should be managed differently according to their main and interaction effects to improve the flow of ED patients.

■ **MD-39**

Monday, 14:30-16:00 - Colville C405, Level 4

Risk and Policy Analytics II

Stream: Decision Processes
Invited session
Chair: *Monica Oliveira*

1 - How to design innovatively public policies?
Irene Pluchinotta, Valentina Ferretti, Alexis Tsoukiàs

The talk addresses the problem of how to support creativity in policy design using formal analytic tools. The issue has been addressed in a less formal way within the policy analysis literature. Despite the existence of "methods" and "procedures" aiming at helping the innovative design of policies, there is no such method using some formal and/or analytical approach. The talk uses some recent real case experiences in order to suggest how decision analytic methods can be used in order to help policy innovation.

2 - Participatory System Based Methods in Asset Based Approaches to Public Sector Reform
Dominic Finn, Susan Howick, Alec Morton

This paper demonstrates potential for the use of Participatory System Based Methods, like System Dynamics and SODA, in Scotland's distinctive Public Sector Reform attempts. Demographic pressures in Scotland suggest future funding problems for continued health and social care. Political legitimacy is under pressure as perceived policy and co-ordination failure generate expenditure without the anticipated results. The Scottish Approach to Public Sector Reform demands short and long-term performance improvements by changing what the state does and how it does it. Evidence from a case study in a Scottish Local Authority, shows that reform in the mould of the Scottish Approach is not straightforward. A suggested route to involve people, improve outcomes and reduce costs, is to use Asset-based Approaches. Theoretical and practical connections between Assets-based approaches and System Based Methods will be discussed.

3 - What Determines Population Health? From Structuring the Multidimensional Population Concept Towards Designing a MACBETH Model to Evaluate Population Health
Monica Oliveira, Carlos Bana e Costa, Diana F. Lopes, Helena Forte, Paulo Nicola, Carlos Freitas

Measuring comprehensively population health is central to understand not only what determines the health of a population, but also to understand which policies should be adopted to improve population health. Although some studies in the literature have developed multicriteria-based population health indices, several definitions of population health exist, multiple index structures have been used, as well as existing studies have not always adopted good decision analysis practices in aggregating indicators and in building weights. Within the scope of the EURO-HEALTHY EU project — which aims at "Shaping EUROpean policies to promote HEALTH equitY' — this study develops a multi-methodology to define and structure population health and to design a MACBETH aggregation-disaggregation model to evaluate population health at the European regional level. The starting point is to link scientific and policy-based evidence with an appropriate definition of population health and with the structuring of a multidimensional population health index using problem structuring tools combined with content analysis. Respecting that multidimensional structure, it will be designed a MACBETH aggregation-disaggregation model to link health indicators with population health in multiple dimensions and with overall population health. The proposed methods will be later applied to build a population health index to evaluate the health of populations from 273 European regions from 28 countries.

■ **MD-41**

Monday, 14:30-16:00 - Colville C512, Level 5

MCDA and Environmental Management II

Stream: Multiple Criteria Decision Aiding
Invited session
Chair: *Luisa Paolotti*

1 - SUNDS, a Multi-Criteria Decision Analysis methodology for nanotechnology sustainability assessment
Alex Zabeo, Elena Semenzin, Danail Hristozov, Vrishali Subramanian, Antonio Marcomini

Sustainable nanotechnology calls for a comprehensive evaluation of risks and impacts of nanotechnologies at an early stage of their life cycle. The proposed sustainability assessment approach is based on an adaptation of the authorisation process currently in operation within the EU REACH regulation. REACH is based on Risk control (RC), demonstrating adequate control of risk due to a substance's use, and Socio-economic Analysis (SEA), demonstrating that benefits of using the substance significantly outweigh societal costs. SEA analyses are

based on the triple bottom line (TBL) approach, which comprises the environmental, economic, and societal 'pillars'. The proposed methodology concerns the integration into a sustainability score of quantitative results from the application of state of the art assessment methodologies for RA and SEA. To face the substantial heterogeneity of information a Multi Attribute Value Theory specific assessment methodology is proposed which is intended to capture input's relations and aggregate results by means of stakeholders' insights. The great level of inherent uncertainty all along the assessment process is managed by the use of specific Fuzzy Logic operators. The proposed methodology will finally be implemented into the SUNDS Decision Support System as a result of the SUN FP7 project. SUNDS will be a web application allowing single assessments as well as integration of all information in an overall sustainability score.

2 - Collaborative Decision Support Systems for Landscape Integrated Assessment

Maria Cerreta, Raffaele Attardi, Carmelo Maria Torre

The definition of Historic Urban Landscape (HUL) by UNESCO is the latest contribution to the debate concerning the identification, conservation, enhancement and management of cultural heritage. UNESCO recommendations refer to the landscape in order to emphasize the systemic behaviour of several factors (economic, environmental, social, cultural) involved and the complexity of the arena. The quality of life is a concept measured in terms of well-being, which is nowadays recognized as a multidimensional variable, extending beyond the traditional approach of GDP. Several studies and international reports on the measurement of well-being include the physical and perceptual quality of the environment as one of the dimensions of well-being. This paper identifies an alternative approach to activate regional policies based on landscape enhancement, in order to positively influence the quality of life. The approach is part of a wider research project that takes into account a multi-dimensional and multi-functional vision of landscape, implemented in the National Park of "Cilento, Vallo di Diano e Alburni' in the Southern Italy. Starting from the above conceptualization, we propose a methodology for the multidimensional landscape evaluation, through the design of a Collaborative-Decision Support System (C-SSD) for context-aware planning strategies, combining Multi-Criteria Analysis (MCA), Multi-Group Analysis (MGA) and Geographic Information Systems (GIS).

3 - Using SIPRES — a fusion of revised Simos' procedure and ZAPROS — in environmental negotiations

Dorota Górecka

Environmental management decisions very frequently cause discussions and disagreement. They involve the number of stakeholders with competing interests and require negotiations in order to resolve conflicts. In a negotiation process, knowing the preferences of the decision-maker and building a negotiation offers scoring system are very difficult tasks. A variety of methods can be used to develop such a negotiation support tool, for instance SAW, TOPSIS or MARS, but they have some disadvantages. In this presentation the issue of evaluating the negotiation template using a new tool called SIPRES is discussed. The algorithm proposed combines the key elements of revised Simos' procedure and ZAPROS method to elicit the negotiator's preferences over some reference solutions. The method is transparent and easy to implement. On the one hand, it allows decision-makers to define their preferences simply and provides a straightforward but effective method for analyzing the trade-offs between the alternatives using selected reference alternatives only (the ZAPROS-like approach). On the other hand, the revised Simos' procedure applied in the method allows determining the cardinal scores for the alternatives. The scoring system obtained this way makes it possible to conduct a sophisticated symmetric and asymmetric negotiation analysis and find an arbitrary solution. Example presented in this work concerns the eco-challenging real-life problem of selection a route for a road.

4 - A novel multi-criteria multi-period approach for selecting projects in sustainable development context

Anissa Frini, Sarah Ben Amor

This paper is concerned with project selection in sustainable development context, which is one of the major concerns of governmental departments whose are seeking to develop best approaches and innovative methods to deal with such complex decision-making problem. For this context, we propose a novel multi-criteria multi-period outranking approach which solves multi-criteria decision-making problems, considering not only their immediate consequences but also their future impact in the short, medium and long term horizons. More specifically, the proposed approach consists of the following three phases: i) problem structuring and preference modeling, ii) multi-criteria aggregation at each period using an outranking method and iii) multi-period

aggregation using a measure of distance between preorders in order to aggregate the results of the multi-criteria aggregation phase at each period. The proposed approach can be used with all outranking methods. In this paper, we illustrate the approach using ELECTRE II but any other outranking method could be used alternatively. The proposed approach is then applied for sustainable forest management decisions. In this context, the consequences of the different forest management options are evaluated over a horizon of 150 years and the main results of the proposed approach are discussed.

■ MD-42

Monday, 14:30-16:00 - McCance MC301, Level 3

Quantitative Analysis in Service Management

Stream: MADM Applications
Invited session
Chair: *Sy-Ming Guu*

1 - Mobile Banking's Intention on Consumers' Intention to Use: The Concepts of Groups, Trust, and Perceived Risk

Shuyen Hsu, Tse-en HuangFu, Tyrone T. Lin

This paper employs a questionnaire survey method and conducts a regression analysis on 203 returned effective samples for a mobile banking industry on consumers' intention to use so as to prove that: 1. reference groups and trust are significantly positively related to the perceived ease of use, perceived usefulness, and intention to use; 2. the perceived ease of use and perceived usefulness are significantly positively related to the intention to use; 3. Perceived risk is significantly positively related to the perceived usefulness and insignificantly related to the intention to use. The research results may help financial institutions to understand the impact of the willingness on consumers to use the mobile banking platform and can be used as a niche of the financial industry to develop its international financial business and the advantage of having good use on banks' trust of consumers to seek a strengthened cooperation with multinational retailers and the service industry.

2 - An Optimal Multinational Fast-Food Enterprise Service System with a Mixed Strategic Game Perspective

Tzu-Hsuan Chen, Tyrone T. Lin

This paper will discuss how a multinational fast-food enterprise and a local fast-food enterprise select a service window under the best economic gains by using a mixed strategic game concept. The income of a fast-food enterprise will be influenced by a service system; therefore, selecting an optimal service system is going to be important in this competitive environment. Assume there are a multinational fast-food enterprise and a local fast-food enterprise at the same competitive area. During peak hours and off-peak hours, both fast-food enterprises would like to select the optimal service system in this competitive environment. The service system under this competitive environment customer distribution is measured in accordance with Poisson distribution and service time is measured in accordance with exponential distribution. This paper introduces the sensitivity analysis for simulating on the single-service system or two-service system to find some key parameters which have the main influences of service system in the competitive and uncertain environment. This paper is expected to provide an appropriate decision analysis paradigmatic for fast-food enterprises to draw up competition policies and copy investments in the future, which will be the main topic of this conference paper.

3 - Core Competence of Action Learning Specialists in Communication Chain Service Provider

Ma Chuan-Yi, Lin Chen

This study attempts to use Modified Delphi and AHP to find a systematic approach to determining the core competence of Action Learning group members who need to have what are the core competencies. "Action Learning" is a method of personal development in the organization, and a learning tasks, However, the results of implementation Action Learning provide statistics to be reference by human resource industries and academic. Through Modified Delphi interviews of experts in this field, then analyze the returned data, and derived a framework of key core competencies factors to the Action learning, and then

converted for multi-level decision-making analysis using AHP questionnaires to the panel of experts to determine relative weightings of the factors to be measured. The cross-examination finding of the key core competence factors are display in the results determined by the respondents. This study is based on a chain in northern Taiwan's largest telecommunications provider as a case of "case study" approach, interviews, action learning team members, try to find out when the case during the "action learning" action learning team members shall possess core competencies , hoping to provide a direction for conducting staff training cases.

4 - The multiple lot sizing problem of a two-stage serial production system with rigid demand and Pentico's heuristic
Sy-Ming Guu

The optimal lot sizing decision problem for a serial production system with rigid demand is well-known difficult for analysis due to often complicated cost expressions and the need to decide optimal lotsizes to stages/machines in the system. Pentico proposed a simple and effective heuristic that all usable items exiting a stage will be processed at the next stage till the end of the system. Pentico's huristic requires only the decision on the initial lot size. Therefore, Pentico's rule could simplify the decision while facing complicated cost expressions.

While Pentico's rule could be viewed as a "heuristic" which simplifies the decision-making in a complicated settings, indeed, Pentico's rule is one kind of real production processes. In our experience with the production process of bi-injection of ski boots (dual colors), the whole process consists of two injections of colors: after the first injection with one color, the semi-finished ski boot is examined and will enter the second stage of injection for the second color only if it is good in quality. If it is defective, then this item won't be processed in the second stage.

In this paper, we study an optimal lotsizing problem for two-stage serial production system with a uniform yield in stage 1 and an interrupted geometric yield in stage 2. In modeling, the uniform yield could be used to represent a whole new equipment/machine/procedure in the process while the interrupted geometric yield could represent a mold.

■ MD-43
Monday, 14:30-16:00 - McCance MC303, Level 3

Defence and Security Applications IV

Stream: Defence and Security Applications
Invited session
Chair: *Ana Isabel Barros*

1 - The effects of a player's recognition about the acquisition of his information by his opponent in an attrition game on a network
Ryusuke Hohzaki, Makoto Tanaka

This paper deals with two-person zero-sum attrition games on a network. An invader starts from a node to reach a destination node, expecting to keep his initial members untouched during the invasion. A defender deploys his forces on arcs to intercept the invader. If the invader encounters the defender on an arc, he incurs casualties according to Lanchester's linear attrition rule. The problem has a variety of applications, such as the omission of data packets and the invasion of malwares in computer networks, and the leakage of water or electricity in infra-networks. By this model we focus on the effects of a player's recognition whether his information is acquisitioned by his opponent.

2 - Protection of critical infrastructure against multiple intruders
Corine Laan, Ana Isabel Barros, Richard Boucherie, Herman Monsuur, Tom van der Mijden

Security forces are often deployed to protect critical infrastructures. In order to derive the best deployment strategy, we construct and analyze an interdiction game that considers multiple simultaneous threats. To this end, we consider a queueing network with positive and negative customers. Intruders route through the network as regular customers, while agents are modeled as negative customers that arrive to specific nodes. When an agent arrives at a node where an intruder is present, the

intruder is removed from the network. Intruders and agents compete over the value of this network, which is the throughput of the intruders that are not intercepted by agents. Intruders attempt to maximize this throughput by deciding on their route through the network, while the agents aim to minimize the throughput by deciding on their arrival rate to each node. We analyze this game and characterize optimal strategies. For special cases, we obtain explicit formulas to evaluate these optimal strategies.

3 - Network Protection Games
Melike Baykal-Gursoy, Andrey Garnaev, Harold Poor

Network security against possible attacks involves making decisions under uncertainty. In this talk, we present game-theoretic models of allocating defense effort among nodes of a network. We derive the unique equilibrium strategy pair in closed form for a simple static game. We consider the case that the network's defender does not know the adversary's motivation for intruding on the network. We illustrate and analyze the consequences of taken this uncertainty into account with a simple Bayesian game model. We show how information about this factor can be used to increase the efficiency of the optimal protection strategy. We also prove that the attack strategy has node-sharing structure.

■ MD-44
Monday, 14:30-16:00 - McCance MC319, Level 3

Fuzzy Multiobjective Programming

Stream: Fuzzy Decision Support Systems, Soft Computing, Neural Network
Invited session
Chair: *Monga K Luhandjula*

1 - Multiobjective Optimization problem with fuzzy random data
Monga K Luhandjula

This paper is devoted to the description of a new approach for dealing with a multiobjective programming problem with fuzzy random data. The key idea behind our approach is to explore, with good reasons,connections between fuzzy random variables and random closed sets. Ways for solving the resulting stochastic program are also discussed. A numerical example is supplemented for the sake of illustration.

2 - Group Decision Making: A Fuzzy Inference System based Optimization Procedure
Mahima Gupta

Group decision making (GDM) becomes a necessary approach to seek a solution to real life complex problems.The complexity of the problem arises due to underlying multiple aspects such as social, political and economical that needs involvement of multiple decision makers to arrive at any decision. In general, members have diverse and often conflicting evaluation system which leads to no consensus solution in the group. In this paper, we have given a methodology that obtains group's consensus view by finding the shift in the members' opinions as dictated by group's dynamics i.e. support of their views in the group and extent of influence on them in the group. The members' preferences for the alternatives are elicited using linguistic terms by comparing pairs of alternatives. The extent of influence on a member is calculated by accounting their 1-step, 2-step and higher relations in the group. Further, their support in the group is calculated by finding similarity between their and group members' opinions. The developed Fuzzy Inference System (FIS) gives a rule base to calculate likely shift in the members' opinions in the form of an interval. The shifts in the opinions are used to calculate revised opinions of the members through an optimization procedure that ensures higher group's consensus than the previous ones. The methodology proceeds iteratively to calculate revised opinion of the members till the time consensus reaches a predefined threshold value.

■ MD-45

Monday, 14:30-16:00 - Graham Hills GH514 Lecture Theatre

Integrated Transport Planning

Stream: Optimization of Public Transport
Invited session
Chair: *Anita Schöbel*

1 - Approaches for integrated planning in public transportation
Anita Schöbel

Planning of a public transportation system is usually done in a sequential way: After the network design, the lines and their frequencies are planned. Based on these, the timetable is set up, and later on the schedules for the vehicles and the drivers. From an optimization point of view such a sequential planning procedure can be regarded as a Greedy approach: in each planning stage one aims at the best one can do. This usually leads to suboptimal solutions. On the other hand, many of these single steps are already NP hard such that solving the integrated problem to optimality seems out of scope.

In this talk we argue that public transportation will benefit from an integrated planning. Weaknesses of the sequential approach will be pointed out. Furthermore, different ways of tackling the integration of line planning, timetabling and vehicle scheduling will be proposed and first results using these approaches will be shown.

2 - Integrated Train Scheduling and Routing in the UK Network
Banafsheh Khosravi, Julia Bennell, Chris Potts

We consider an integrated train scheduling and routing problem in tactical and operational level. The train scheduling and routing problem is formulated as a modified parallel machine job shop scheduling problem. The aim is to determine train routes among alternative options whilst simultaneously identifying their timing and relative ordering. The model can be solved in both tactical planning level and in respond to disruptions in operational level. We try to minimise delay propagation in the network subject to a set of operational and safety constraints. A generic Mixed Integer Linear Programming (MILP) model of the problem is developed which can be adapted to different rail networks. A novel algorithm based on the Shifting Bottleneck (SB) heuristic is introduced to solve the integrated train scheduling and routing problem. We explore the performance of the suggested algorithm with a case study based on the part of the UK railway network. Analyses of the mentioned critical corridor with a complex infrastructure and congested traffic indicates the computational advantages and viability of the suggested method.

3 - Rolling stock circulation and maintenance optimization
Ángel Marín, Luis Cadarso, Javier Andrés

Usually a sequence of planning problems must be solved rail scheduling, rolling stock, and routing: given a train scheduling, the rolling stock determine which type and composition train operate, considering the passenger demand. Once the train type is assigned to routes, the routing problem may be solved for each train separately satisfying maintenance restrictions. This approach might lead to suboptimal allocation of trains, since a solution of one of the problems may restrict the set of feasible solutions of the problem solved later. In this paper the rolling stock circulation and train routing are simultaneously studied. This is a fairly complex problem which requires the use of decomposition methods in order to obtain higher-quality solutions that allow the efficient arrangement of the trains. Under the perspective of rolling stock maintenance routing, a model to minimize the cost of train service and maintenance assignation to each individual train is studied. This model will require total service coverage by the rail fleet and passengers with a minimum amount of rolling stock units, trying to avoiding empty services. We evaluate the performance different solution methods consisting basically on use Branch and Bound or Branch and Price. The integrated model and methods are evaluated with preliminary computational experiments for real case studies drawn from RENFE (the main Spanish train operator).

4 - Maintenance Location Routing for Train Units: An Agenda for Research
Denise Tönissen, Joachim Arts, Geert-Jan van Houtum

The Maintenance Location Routing Problem (MLRP) for Train Units is a problem where we locate maintenance locations, while also taking the maintenance routing into account. To our best knowledge, this is a new problem which has never been studied before. We argue that taking facility location and maintenance routing decisions jointly is important for this problem and study approaches for similar problems in the literature. We identify several complicating features of a joint approach in the railway environment. The most important of these is that routing feasibility is more of an issue than minimizing transportation cost. We suggest an agenda for research that deals with all these features. In particular we propose to tackle the MLRP in the following steps: 1) Generate feasible routes to possible candidate facility locations by solving a multi-commodity flow problem for every train type in a rolling horizon fashion. 2) Open candidate locations by combining feasible location-routes for all train types. Such combinations can be found by solving a generalization of the hitting set problem. We also discuss possible extensions of the problem which include unexpected failures of train units, several types of disruptions of the rolling stock schedule, and capacity sizing for maintenance locations.

■ MD-48

Monday, 14:30-16:00 - Graham Hilils GH510, Level 5

Supply Chain Network Design

Stream: Location
Contributed session
Chair: *Olivier Péton*

1 - A revised encoding and decoding structure for supply chain network design problems
Zehra Kamisli Ozturk, Mehmet Alegoz

A regular supply chain network consists of suppliers, manufacturing plants, warehouses and distribution centers. In this context, supply chain network design is determining the number, capacity and place of the facilities and determining the flow between them. Supply chain network design problem is considered to be an NP-Hard class problem which means that the solution time increases non-polynomially when the problem size increases. For this reason, especially, for big dimensional problems it is necessary to use metaheuristics. The solution quality of the used metaheuristics depends directly on the encoding and decoding structure. In this study, we have proposed a revised encoding and decoding structure which bases on priority based encoding. We have used tabu search algorithm as an example and in order to show the efficiency of the proposed structure. The computational results showed that the proposed structure gives high quality solutions within a reasonable time. It is also possible to use this encoding and decoding structure with some other metaheuristics like genetic algorithm.

2 - A MIP model for facilities location in freight logistic networks with externality costs
Anna Sciomachen, Daniela Ambrosino, Claudio Ferrari, Alessio Tei

We analyze the effects of locating logistics platforms within intermodal networks that might serve a market through different transport alternatives, in terms of transport modes, costs and distances. We focus on the flow coming from maritime terminals, where a key element is the location of logistics parks in terms of effectiveness of the logistics corridors. The underlying model is a weighed capacitated multimodal network, where logistics platforms to locate and origin — destination (o-d) demands are given; we then have to allocate o-d demand to the chosen platforms so to minimize the total logistic costs and satisfy the capacity restrictions related to both facilities and arcs. Transportation, operative and fixed opening costs are given. Note that the design of the logistic system has here a great impact on the externalities created by transportation; therefore, costs upon society imposed by the side effects of transport activities as road congestion costs, pollution, road and rail noise costs and incidentally ones are considered. Another innovative aspect is the possibility of splitting the required o-d demand into several paths using different travelling modes and logistics platforms. We present a MIP model of the problem for dealing with real size instances. Results of an extensive computational experimentation, using the commercial solver CPLEX 12.5 are reported, showing the effectiveness of the proposed model. Additionally, the Ligurian ports network is analyzed.

3 - A facility location problem for the design of a collaborative distribution network

Olivier Péton, Fabien Lehuédé, Xin Tang

We consider a multi-echelon collaborative distribution network between a cluster of suppliers from the same economic sector and the geographical area to thousands of customers spread over a large territory. The suppliers wish to set up a collaborative distribution network based on one consolidation facility in the production area and a collection of intermediate logistics facilities called regional distribution centers (RDC). This distribution system combines full truckload (FTL) routes between the production area and the RDCs and less-than-truckload (LTL) shipments from the RDCs to each customer.

We propose a mixed integer linear programming formulation for the optimal location of regional distribution centers. This model integrates the two transportation rate structures, considers the high impact of seasonality and enables direct deliveries from the production area to customers when FTL routes are not profitable.

We show how this model can be used in practice by decision makers. In particular, we propose two additional constraints that help decision makers to refine their preferences. We present computational experiments on a case study concerning the distribution of horticultural products in France.

■ MD-49

Monday, 14:30-16:00 - Graham Hills GH511, Level 5

Adaptive Search

Stream: Metaheuristics
Invited session
Chair: *Dorabela Gamboa*

1 - Lagrangian RAMP Algorithms for the p-Median Problem

José Veloso, Dorabela Gamboa, Cesar Rego

Given a set of potential locations and a set of geographically distributed customers, the p-Median problem is to locate p facilities (medians) so that the sum of the distance from each costumer to the closest median is minimized. The p-Median problem is NP-Hard. Many real-world applications of the problem are of very large scale; therefore, advanced heuristic methods are often required to find near-optimal solutions in reduced computation times. We present two new algorithms for the p-Median problem based on the Relaxation Adaptive Memory Programming (RAMP) approach. The algorithms combine Lagrangian relaxation with the evolutionary Scatter Search method to explore primal-dual relationships throughout the search. Both algorithms proved very robust, producing high quality solutions very efficiently on a large set of benchmark instances.

2 - An adaptive large neighborhood search metaheuristic for the bike request scheduling problem

Nicholas Vergeylen, Kenneth Sörensen

We present an adaptive large neighborhood search metaheuristic for the static bike request scheduling problem, a novel approach to tackle city bike repositioning problems. The metaheuristic uses several dedicated local search heuristics and adapts their frequency of use to their historic performance. The results of this method are discussed and compared to those of an exact method developed in previous research.

3 - An adaptive large neighborhood search algorithm for agile satellite scheduling

Xiaolu Liu, Gilbert Laporte, Renjie He, Feng Yao

An agile satellite is a new generation of satellite which has three degrees of freedom for acquiring images on the Earth ground. As a result, it has longer visible time windows for requested targets. The shot of image can be conducted at any time in the window if and only if the left time is long enough for the fulfillment of imaging. For an agile satellite, a different observation time means a different image angle, bringing in a different transition time from its preceding task. Therefore, the setup time for each imaging process depends on the selection of its observation start time, making the problem a time-dependent scheduling problem. To solve it, we develop a metaheuristic, called adaptive large neighborhood search (ALNS) algorithm, thus creating

a conflict-free observational timeline. ALNS is a local search framework in which a number of simple operators compete to modify the current solution. To use ALNS, we define 5 removal operators for destroy neighborhood and 3 insertion operators for repair neighborhood. At each iteration, a pair of operators is selected to destroy the current solution and generate a new solution according to the result of adaptive layer, with a large collection of variables modified. Time slack is introduced to confine the propagation of the time-dependent constraint of transition time. From comparison experiments with an ant colony optimization algorithm, the results show that ALNS performs better, fulfilling more tasks with a good robustness.

4 - A Dual RAMP Algorithm for the Capacitated Facility Location Problem

Telmo Matos, Dorabela Gamboa, Cesar Rego

We address the classical Capacitated Facility Location Problem (CFLP) in which the assignment of facilities to customers must ensure sufficient facility capacity and each customer is served by only one facility. A Relaxation Adaptive Memory Programming (RAMP) approach is proposed to find near-optimal solutions for the CFLP. Our method combines Lagrangian Subgradient Search with a simple Tabu Search to explore primal-dual relationships as a way to create advanced memory structures that integrate information from both primal and dual solution spaces. The algorithm was tested on the standard testbed of ORLIB for the CFLP and efficiently found the optimal solution for all instances. Comparisons with current best performing algorithms for the CFLP show that our RAMP algorithm exhibits superior performance, especially on large-scale instances.

■ MD-50

Monday, 14:30-16:00 - Graham Hills GH512, Level 5

Yard Management

Stream: Container Terminals
Invited session
Chair: *Noorul Shaiful Fitri Abdul Rahman*

1 - A New Formulation for the Container Pre-Marshalling Problem and an Efficient Solution Using a Variable Chromosome Length Genetic Algorithm

Amr Eltawil, Mohamed Gheith

In this work, a new formulation for the pre-marshalling problem based on the multi-commodity network flow problem is presented. The binary mathematical programming model is used to find the optimum solution for small sized problems. The model is successfully validated by comparing it to the model presented by Lee and Hsu (2007). The model is used to solve the instance of Lee and Chao (2009) that is believed not to have been solved to optimality before. In order to solve larger problems, another heuristic based solution using a variable chromosome length genetic algorithm is presented. The standard genetic algorithm structure is modified and new functions are introduced in order for the proposed algorithm to be able to solve the pre-marshalling problem. The algorithm is validated by comparing it to the small benchmark instances. In order to check the efficiency and effectiveness of the developed method, the results were compared to 80 randomly generated instances presented by Caserta and Voss (2009). The proposed variable chromosome length genetic algorithm is able to find better solutions in most of the cases and in reasonable time.

2 - Bidirectional Search using the Abstraction Heuristics for the Container Relocation Problem

Tiru Arthanari, Dusan Ku

The container relocation problem or the blocks relocation problem is a classic combinatorial optimisation problem that occurs in day-to-day operations for facilities that use block stacking systems. A typical place where this problem arises is a container terminal where containers can be stacked vertically in order to utilise the scarce resource of yard surface, thus at times resulting in the unproductive reshuffling moves for containers stacked above the target container for retrieval. Due to the problem class being NP-hard, a number of studies on this topic propose heuristic approaches to solve this problem. There are a few exact methods, either search-based algorithms or mathematical programming, proposed for this problem, but the feasible problem size of such methods is quite restricted, limiting their practical significance.

In this paper, we propose as a search-based algorithm a new search method called the abstraction heuristics, which can significantly reduce the search space of this problem. Our computational results confirm that our approach enables instances of practical size to be solved optimally within a reasonable computation time.

3 - Modelling and Multiobjective Optimization for Automated Guided Vehicles at Container Terminals
Anita Gudelj, Maja Krčum

The objective of this study is to model and optimization of an Automated Guided Vehicle System which is embedded in a container terminal. Typical operational and control requirements of such systems include: scheduling AGVs and containers in the terminal, routing of AGVs and controlling of vehicular traffic in the transportation network. In this study, one particular aspect of the terminal operations is considered, that of scheduling AGV jobs. The aim of AGV scheduling is not only reduces the cost of terminal operation but also maximizes the system performance. This study first formulates mathematical model which is focused on the optimization of job scheduling. The model considers two objectives (i.e., AGV traveling time and the number of AGVs involved) and their weighted sum is investigated as the representative example. The moving of vehicles can be described as the set of discrete events and states. In addition to this a Petri net model which represents the transportation of containers from pick-up locations to delivery is introduced. The study is extended to seek optimal, conflict and deadlock free schedules in AGV system using an algorithm which integrates MRF1 class of Petri net with a genetic algorithm which yields improvements in system throughput along with a decrease in the numbers of AGVs. The algorithm deals with multiconstrained scheduling problem with shared resources. The developed model is verified by a computer simulation using MATLAB environment.

4 - A Potential Solution for the Space Limitation Problem of the Container Stacking Yard at Port Klang
Noorul Shaiful Fitri Abdul Rahman

Over the ten years, maritime industry had experience in tremendous growth and provides numerous incomes to Malaysia. The total number of containers handled by Port Klang is keep increasing almost doubled every year because it is the main gateway by sea of Malaysia. Thus, it creates a problem of accommodating the container demand due to the limited size of container yard space owned by Port Klang. Port Klang has ranked as the 12th busiest container port (in year 2012) in the world. Thus, it becomes a serious issue as the container business is the main source of income to this particular port. Now, Port Klang is in the progress of building the third port as a short term solution in order to accommodating the growing container demand due to the existing Northport and Westport are only capable to cater the port users until 2016. The objective of this study is to introduce a new innovation of container stacking storage as a potential solution for overcoming the container yard space problem at Port Klang. The new innovation concept is adopted from the existing application of an Automatic Parking System incorporates with green technology concept. This model is suitable to be implemented in solving the space limitation problem at the container port. Finally, it enables to increase the efficiency and effectiveness of handling containers, and the profit margin of Port Klang as the high level of container stacking storage is almost triple than normal.

■ MD-51
Monday, 14:30-16:00 - Graham Hills GH542, Level 5

Freight Transport

Stream: Traffic and Transportation
Invited session
Chair: *Tsung-Sheng Chang*

1 - Comparing cost allocation methods for consolidation in intermodal transport
Katrien Ramaekers, An Caris, Lotte Verdonck

Policy makers at European as well as regional levels express the need to stimulate intermodal transport chains. A growing market share for intermodal transport should mean a shift towards more environmental friendly transport modes, less congestion and a better accessibility of

seaports. Consolidation of freight flows is often suggested to improve the efficiency of intermodal operations Shippers attain scale economies and a better utilization of transport equipment through consolidation of freight inside a loading unit. Questions rise how benefits may be allocated among the participants in the cooperation. No studies have yet been performed on cost allocation methods for collaboration between shippers aimed to make use of intermodal transport. In this research, several cost allocation methods are presented to allocate the cost savings of consolidation among the participants in this type of cooperation. While economies of scale are an obvious advantage for the consolidation of freight flows as a whole, the benefits for a single member are not always clear. The allocation of the benefits of consolidation to the individual members may cause lack of commitment and hesitation to take part in the consolidation. Very simple and straightforward cost allocation methods are compared to more advanced methods based on cooperative game theory.

2 - Real-Time Decision Support for Truckload Carriers Participating in Multiple e-Procurement Auctions
Tsung-Sheng Chang

The objective of this paper is to develop decision support to help truckload (TL) carriers participating in multiple e-auctions to tackle bidding-related contingencies (uncertain events) in real time. At the beginning of a day, the TL carriers integrate the bidding information in multiple e-marketplaces with their current fleet statuses to optimize their fleet deployment plans and accordingly make bidding decisions. During the course of the day, new information such as locating new auctioned loads, winning auctioned loads and losing auctioned loads may pop up any time. The TL carriers must therefore have the ability to optimally re-deploy their fleets based on emerging uncertain events and accordingly adjust existing and/or propose new bidding strategies whenever they are necessary in real time. Hence, this research proposes a decision support tool mainly with a built-in scenario-based contingency planning model to enable the TL carriers to possess such ability. To our knowledge, there are no previous contributions proposing bidding decision support for TL carriers in such a dynamic and uncertain environment.

■ MD-52
Monday, 14:30-16:00 - Graham Hills GH554, Level 5

Finance, Insurance and OR

Stream: Financial Mathematics and OR
Invited session
Chair: *Azar Karimov*
Chair: *Gerhard-Wilhelm Weber*
Chair: *Mustafa Pinar*
Chair: *Erdem Kilic*

1 - Constant Proportion Portfolio Insurance with Conditional Floor
Jean-Luc Prigent, Hachmi Ben Ameur

Portfolio insurance strategies allow the investors to limit downside risk, while benefiting from market rises. They are particularly attractive for investors who do not want to lose part of their initial investment. It corresponds also to the main structured portfolio management and has been recently emphasized by the financial crisis. One of the main portfolio insurance method is the Constant Proportion Portfolio Insurance (CPPI) (see Prigent, 2007). The main objective of this paper is to present and analyze various CPPI type methods based on conditional floors, within a rather general parametric model. In this model, the floor can be modified according to market fluctuations and portfolio management goals. We use both Value-at-Risk and expected shortfall criteria to manage the gap risk. Our extensions allow the investors to make profit from market performances, while keeping part of their past gains. We illustrate the comparison and the effectiveness of all these strategies on S&P data.

2 - Optimal Control of Stochastic Hybrid Delayed Models with an Application to Finance
Emel Savku, Gerhard-Wilhelm Weber

Stochastic Hybrid Models are continuous-time dynamics with discrete components and this heterogenous structure make them natural and powerful candidates to model abrupt changes in the financial market. Regime switching models may capture not only the sudden changes of behavior of financial markets but also the new dynamics and fundamentals persist for several periods after a change. In this framework, we establish sufficient maximum principle for the optimal control of a time-delayed stochastic hybrid model. The associated adjoint processes are shown to satisfy a time-advanced backward stochastic differential equation (ABSDE). Also, we study on the extension of necessary maximum principle for such a system and purpose to apply our results for portfolio optimization problems in finance.

3 - Mean-Variance Portfolio Models for Portfolio Selection with Interval-valued Objective Function and Fuzzy Risk Factors
Mbairadjim Moussa Alfred

Fuzzy random variable is introduced by Puri and Ralescu (1986) and Kwakarnaak (1978) as mathematical tool for imprecise information modeling or to represent uncertainty about classical random variables. Its expected value is commonly defined via the Auman expectation operator, however, various notions of variance were introduced over these last decades for its characterization. This literature defines the variance as a real number by the Frechet principle or as a fuzzy or crisp set. In this latter approach, Couso and Dubois (2009) define the variance as a closed interval offering a gradual description of the incomplete knowledge about the variance of an underlying, imprecisely observed random variable. Adopting this definition, we propose a mean variance portfolio selection model assuming that the risk factors are fuzzy random variables and the objective functions are interval-valued. We propose some solutions by applying the results of Bhurjee and Panda (2012) on interval optimization problems. Finally, numerical illustrations based on real dataset are presented in order to show the effectiveness of the method.

4 - An Application of Log-linear Models for Contingency Tables
Coskun Parim, Serpil Kılıç Depren

Log-linear models are frequently used for cross-classified data. The best-fitted model selection is a very important issue for log-linear models. Generally, Chi-square and deviance statistics are used to select the best-fitted model. In this study, "Saturated", "Additive" and "Minimal" Log-linear models are investigated and a real data application is performed by using R software. The purpose of this study is to decide the best-fitted model on high dimensional contingency tables. All interactions are shown and the best model is determined according to goodness of fit statistics and comparison criteria.

■ MD-53
Monday, 14:30-16:00 - Graham Hills GH614, Level 6

Stochastic Models

Stream: Dynamical Systems and Mathematical Modelling in OR
Invited session
Chair: *Hiroshi Toyoizumi*

1 - Reversibility of a 2RRW and its related queueing network
Masahiro Kobayashi

We consider a two dimensional reflecting random walk on the nonnegative integer quadrant. It is assumed that this reflecting random walk has skip free transitions. We are concerned with its time reversed process assuming that the stationary distribution exists. In general, the time reversed process may not be a reflecting random walk. In this talk, we derive necessary and sufficient conditions for the time reversed process also to be a reflecting random walk. Using this result, we also obtain the condition of a queueing network which has a stationary distribution in closed form.

2 - Simulation-based parametric optimization for pull-controlled manufacturing systems
Atsushi Inoie

The pull-controlled manufacturing systems are widely adopted in many industrial companies. Actually it is important to determine the control parameters of such manufacturing systems. We consider the simulation-based optimal setting (SBOS) algorithm proposed by Ohno (2011) which is an optimization algorithm for control parameters. The SBOS algorithm is effective in finding an acceptably good solution in an acceptable amount of time. Here we further improve the SBOS algorithm to reduce the computation time and we apply the typical pull controlled system such as Kanban control system, base-stock control system and extended-Kanban control system. Our numerical results indicate that our algorithm outperforms the existing optimization algorithm in terms of computation time and average cost, and that our algorithm is applicable to a large-scale manufacturing system.

3 - Modelling Warranty Costs using Geometric Repair Times
Sarah Marshall, Richard Arnold, Stefanka Chukova, Yu Hayakawa

The costs associated with meeting product warranty obligations can be significant, and therefore accurate estimation of the expected warranty cost is crucial. A typical assumption in warranty cost analysis is that the repair time associated with a warranty claim is zero. This can lead to inaccurate estimation of warranty costs as the cost of warranty claims are often dependent on the length of the repair time. Whilst some research has incorporated non-zero repair times, the repair time is typically assumed to be independent of the age of the product. This research extends the literature by modelling consecutive repair times as an increasing geometric process. Warranties are often modelled using alternating renewal processes, in which both the operational time ("on time") and repair time ("off time") are modelled using renewal processes. This paper uses a generalised alternating renewal process (GAR), in which the operational time is modelled using a renewal process and the repair time is modelled using a geometric process. The expected cost over the warranty period and life cycle of the product are derived under both a non-renewing free repair warranty (NRFRW) and a renewing free repair warranty (RFRW). Properties of the model are explored using a simulation study and estimated expected costs from the simulations are presented.

4 - Particle Survival Model and Limit Order Books
Hiroshi Toyoizumi

The particle survival model, which was originally proposed to analyze the dynamics of species' coexistence, has surprisingly been found to be related to a non-homogeneous Poisson process. It is also well known that successive record values of i.i.d. sequences have the spatial distribution of such processes. In this research, we show that the particle survival model and the record value process are indeed equivalent. Further, we study their application to determining the optimal strategy for placing selling orders on stock exchange limit order books. Our approach considers the limit orders as particles, and assumes that the other traders have zero intelligence.

■ MD-54
Monday, 14:30-16:00 - Graham Hills GH617, Level 6

Recent Advances in Dynamics of Variational Inequalities and Equilibrum Problems 2

Stream: Recent Advances in Dynamics of Variational Inequalities and Equilibrum Problems
Invited session
Chair: *Patrizia Daniele*

1 - Fashion Supply Chain Network Competition with Ecolabelling
Anna Nagurney, Min Yu, Jonas Floden

We develop a competitive supply chain network model for fashion that incorporates ecolabelling. We capture the individual profit-maximizing behavior of the fashion firms which incur ecolabelling

costs with information associated with the carbon footprints of their supply chains revealed to the consumers. Consumers, in turn, reflect their preferences for the branded products of the fashion firms through their demand price functions, which include the carbon emission information. We construct the underlying network structure of the fashion supply chains and provide alternative variational inequality formulations of the governing Nash equilibrium conditions. The model, as a special case, also captures carbon taxes. We discuss qualitative properties of the equilibrium product flow pattern and also propose an algorithm, which has elegant features for computational purposes. We provide both an illustrative example as well as a variant and then discuss a case study with several larger numerical examples.

2 - Cutting Surface Methods for Equilibria
Giancarlo Bigi, Giandomenico Mastroeni, Mauro Passacantando

The abstract equilibrium problem (EP) provides a rather general setting which includes several mathematical models such as optimization, variational inequalities, fixed point and complementarity problems, Nash equilibria in noncooperative games. It is well known that a pseudomonotone EP is equivalent to minimize the so-called Minty gap function. Though it is a convex function, it can be difficult to evaluate since this requires to solve nonconvex optimization problems. The aim of this talk is to present cutting type methods for solving EP via the Minty gap function, relying on lower convex approximations which are easier to compute. These methods actually amount to solving a sequence of convex optimization problem, whose feasible region is refined by nonlinear convex cuts at each iteration. Convergence is proved under suitable monotonicity assumptions. The results of preliminary numerical tests on Nash equilibrium problems with quadratic payoffs, other linear EPs and variational inequalities are also reported.

3 - Generalized Nash Equilibria for the Service Provisioning Problem in Multi-Cloud Systems
Mauro Passacantando, Danilo Ardagna, Michele Ciavotta

The adoption of Cloud technologies is steadily increasing. In such systems, applications can benefit from nearly infinite virtual resources on a pay-per-use basis. However, being the Cloud massively multitenant and characterized by highly variable workloads the development of more and more effective provisioning policies assumes paramount importance. Boosted by the success of the Cloud, the application of Game Theory models and methodologies has also become popular, since they have been demonstrated to suit perfectly to Cloud social, economic, and strategic structures. This paper aims to study, model and efficiently solve the cost minimization problem associated with the service provisioning of SaaS virtual machines in multiple IaaSs. We propose a game-theoretic approach for the runtime management of resources from multiple IaaSs providers to be allocated to multiple competing SaaSs, along with a cost model including revenues and penalties for requests execution failures. A distributed algorithm for identifying Generalized Nash Equilibria has been developed and analysed in detail. The effectiveness of our approach has been assessed by performing a wide set of analyses under multiple workload conditions. Results show that our algorithm is scalable and provides significant cost savings with respect to alternative methods (80% on average). Furthermore, increasing the number of IaaS providers SaaSs can achieve 9-15% cost savings from the workload distribution on multiple IaaSs.

■ MD-60
Monday, 14:30-16:00 - Graham Hills GH813, Level 8

Network Flows

Stream: Routing I - Models and Methods
Invited session
Chair: *Paola Festa*
Chair: *Francesca Guerriero*

1 - Strategies for Solving the Multi-Objective Spanning Tree Problem to Optimality
Luigi Di Puglia Pugliese, Francesca Guerriero, José Santos

The Spanning Tree Problem (STP) is addressed. The growing demand in quality of services imposes to take into account more than one objective to be optimized. The multi-objective optimization allows to handle problems in presence of conflicting criteria simultaneously. The

multi-objective STP (MOSTP) arises in several applications mainly in telecommunication field. Despite its practical importance and due to its NP-hard complexity, the MOSTP has received little attention. The bi-objective counterpart has been considered in the scientific literature and optimal solution methods have been devised. To the best of our knowledge, only one paper deals with optimal solution approaches for the MOSTP showing empirical behaviour on instances with up to five criteria. This work extends an optimal approach, defined by the same authors, improving its performance. The main idea is to construct a modified network composed by states and transitions, in which each path from an initial state to a terminal one corresponds to a tree in the original graph. Theoretical properties are derived showing the correctness of the construction procedure. The proposed technique has been tested on a wide number of random generated instances. A comparison with the state-of-the-art approaches is also carried out.

2 - Energy Efficient Pollution Routing Problem with Heterogeneous Fleet and Time Windows
Giusy Macrina, Francesca Guerriero, Luigi Di Puglia Pugliese

Nowadays, the air pollution is one of the most serious environmental problems in the world. Due to the growth in the influence of transport, which is a primary source of pollution emissions, on the environmental problems, the definition of sustainable logistics system becomes the main objective of many countries. In this perspective, routing problems can be viewed within a new framework, where the goal is the trade-off between saving operation costs and negative externality reduction. In this paper, we investigate a variant of the Green Vehicle Routing Problem (GVRP). In particular, we consider a heterogeneous vehicle fleet composed by electric and traditional (gasoline/diesel) vehicles. Since the electric vehicles have a limited autonomy of the battery, the possibility of recharging partially at any of the available stations is permitted. Referring to the classical vehicles, we model the pollution emission with a function of both travelled distance and weigh of transported goods. Furthermore, we consider customer time windows and limited vehicle freight capacities. The objective of the model is the minimization of the recharging cost and the reduction of pollution emissions. Preliminary computational tests have been carried out to assess the validity of the proposed mathematical model considering several realistic scenarios.

3 - The Continuous Time Service Network Design Problem
Natashia Boland, Mike Hewitt, Luke Marshall, Martin Savelsbergh

As internet business drives increased consumer expectations of delivery services, logistics services have felt increasing pressure to meet tighter deliver timeframes. In designing their service delivery networks, consolidation carriers must schedule truck dispatch operations so as to deliver goods within service time windows, while exploiting consolidation opportunities to minimize transport costs. Discretization of time, such as underlie traditional time expanded network approaches, can yield strong integer programming models, but the large scale of these formulations often prohibits their solution. Here we provide a method that is far faster and more efficient than the traditional approach, able to find and prove optimality of a solution while generating only a very small fraction of the complete time expanded network.

■ MD-61
Monday, 14:30-16:00 - Graham Hills GH816, Level 8

Green Routing and Logistics

Stream: Routing II - Emerging Applications
Invited session
Chair: *Richard Eglese*

1 - Environmental Sustainability in Logistics — the Contribution from Vehicle Routing
Richard Eglese

Environmental sustainability is an area of concern for the transportation of goods. Negative environmental effects in logistics may arise from issues concerning such things as noise and safety, but this review will concentrate on Greenhouse Gas (GHG) emissions that result from logistic activities. The models that are used to estimate the GHG emissions for road vehicles will be presented and compared to show the inputs that are needed and the outputs they provide. Various approaches

that use these models to plan vehicle routes will be compared, particularly considering whether time-independent or time-dependent models are used and whether the speed of the vehicles is regarded as fixed or variable within the models. The scale of reduction in GHG emissions that is achievable through the adoption of vehicle routing systems will be examined and compared to the effect on GHG emissions from other factors such as the type and capacity of the vehicles used and the opportunities for backhauls and collaboration.

2 - Solving the Green Capacitated Vehicle Routing Problem with Backhauls at Eroski: A Revisited Case Study
Javier Faulin, Javier Belloso, Angel A. Juan, Adrian Serrano

Environmental management principles are gaining interest in today's highly competitive environment. The green logistics improvements presented in this paper are twofold. As a general framework, we consider the Vehicle Routing Problem with Backhauls (VRPB), where delivery and pick-up customers are to be served from a central depot. At the same time, the minimization of the CO_2 emissions is included into the objective function as well as the minimization of distance. Our resolution procedure uses a multi-start approach designed to avoid the local minima and to be easily parallelizable. The algorithm employs a biased-randomized version of the classical savings heuristic, together with some local search processes. During the solution-construction process, the edges that connect one delivery customer with a pick-up customer are penalized to be chosen at a later stage. The savings list of edges is randomized using a skewed probability distribution. This case study has been revisited in relation to the version published by Ubeda et al. (2011), in order to show the potential improvements that can be achieved by applying the above practices. Eroski, one of the leader companies of the Spanish food distribution sector, has been chosen to check the accuracy of our approach.

3 - The Fleet Size and Mix Pollution-Routing Problem
Tolga Bektas, Çağrı Koç, Ola Jabali, Gilbert Laporte

This paper introduces the fleet size and mix pollution-routing problem which extends the pollution-routing problem by considering a heterogeneous vehicle fleet. The main objective is to minimize the sum of vehicle fixed costs and routing cost, where the latter can be defined with respect to the cost of fuel and CO_2 emissions, and driver cost. Solving this problem poses several methodological challenges. To this end, we have developed a powerful metaheuristic which was successfully applied to a large pool of realistic benchmark instances. Several analyses were conducted to shed light on the trade-offs between various performance indicators, including capacity utilization, fuel and emissions and costs pertaining to vehicle acquisition, fuel consumption and drivers. The analyses also quantify the benefits of using a heterogeneous fleet over a homogeneous one.

4 - A CO2 Emissions Minimization Based Model for the Vehicle Routing Problem
Abdelkader Sbihi

Among today's green agenda objectives, greening the routes aims to implementing environmentally friendly routing solutions to reduce the CO_2 emissions. In this research work, we present a transportation model that aims at minimizing routing costs while minimizing CO_2 emissions due to the vehicles journey. Mathematically, the objective includes two types of cost functions to minimize: (i) economic cost related to the route cost and (ii) environmental cost which is evaluated by considering the CO_2 emissions cost. The presented model is seen as a CVRP with an additionnal green objective to sustain the transportation in any logistical system. We have developed some near-optimal based heuristics based methods to solve the problem. The approaches were able to highlight the effectiveness of our model and encouraging results have been obtained to go further in helping to build cleaner routes by accurately computing the CO_2 emissions.

■ MD-62
Monday, 14:30-16:00 - Livingstone LT203, Level 2

Operations Research 4

Stream: Operations Research, other
Contributed session
Chair: *Ira Haavisto*

1 - Cross-organizational learning loop of disaster response
Ira Haavisto, Gyöngyi Kovács, Peter Tatham

This study examines the concept of the learning loop in disaster response as it applies to the period between the assessment of a particular response to the commencement of planning for the next response. The focus is on the humanitarian actors (e.g. regional responders and humanitarian organizations) who respond to a disaster. The disaster cycle assumes that a learning loop exists between the outcome of disaster response and recovery towards the next planning (i.e. prevention) phase. However recent research has highlighted that there is limited connectivity between the end phase in a response (assessment of outcome and impact) and the beginning of a new response (planning). The aim of the study is, therefore, to build on existing disaster cycles and the dynamic model of cross-organizational learning and, thereby, contribute to the conceptual understanding on cross-organizational learning by applying it to the humanitarian context. The concept of organizational learning in this study is understood as "an inquiry into patterns of organizing among two or more people that leads to new knowledge and change in those patterns of organizations'. Cross-organizational learning (also referred to as collaborative learning) requires a network to exist and in this context reflects "how organizations, in cooperation with each other, through formal channels, learn'. In this study the learning-loop between the assessment of response to planning for disaster response is mapped.

2 - Applying DEA to Determine Where To Install Vocational Schools
Fabio da Costa Pinto, Armando Zeferino Milioni, Mischel Carmen N. Belderrain

This article proposes a methodology that will help decision makers to identify cities to install vocational schools.

The cities will be classified by regions according to a template previously determined by entities that represent the industrial sector. Data Envelopment Analysis (DEA) will be applied to rank which cities have the potential to support a vocational school. The criteria used by DEA were defined by stakeholders of a group of vocational schools. The results will be compared with the industrial investments scenarios planned by the Government to each region, to validate the choice of the applicant city.

3 - Interplanetary trajectory optimization, a Mars Mission
M. Navabi, Parvin Keyvani

When a spacecraft travels from the parking orbit to the other planets orbit, due to the huge distances between the planets, very much fuel is needed. Since fuel carrying is not possible given the magnitude of the distance, to achieve interplanetary mission must use gravity assist maneuvers. These maneuvers encounter some restrictions, such as the optimal alignment of the planets to reach the target celestial body. There are assumptions to simplify the problem into a solvable problem. Trajectory design is done using the rules of orbital mechanics and Lambert's problem and numerical optimization search methods. Gravity assist maneuver equations derived and objective function is provided based on C3 min. Then a Mars mission using Venus gravity assist maneuver and free return mission to Mars with Mars gravity assist maneuver is simulated. The Results of the numerical optimization show that obtained trajectory in an minimum-fuel trajectory.

4 - Optimal Harvest in a Multispecies Age Structured Fishery Model at Different Level of Density Dependency
Diwakar Poudel, Stein Ivar Steinshamn

This study suggests optimal harvest in a multispecies age structured fishery model at different level of density dependency. This is an application of the theoretical model by Steinshamn (2011) and highlights that stock density dependency plays a greater role in optimal management. The theoretical model is applied to the Northeast Arctic Cod and Capelin in Barents Sea. We study different scenarios of stock density for a predator-prey ecosystem to investigate the optimal harvest policy in multispecies environment. Among others, we also include the sustainability constraint in the model that contributes towards the ecosystem based management. Our preliminary findings are that smooth but lower harvest is optimal for capelin fishery compared to the single species model. While pulse fishing yields higher value in cod (predator) compared to the current fishing policy because of the lower cost of harvesting due to density dependency.

■ MD-66

Monday, 14:30-16:00 - Livingstone LT209, Level 2

Network Design

Stream: Optimization
Invited session
Chair: *Inmaculada Rodríguez Martín*

1 - Cabled network design optimisation
Vincent Angilella, Matthieu Chardy

The deployment of Fiber To The Home technologies is currently one of the most challenging issues for telecommunication operators. This work focuses on the cabled network design problem, including separation costs. Although several works consider this problem using a flow-like formulation, few of them tackle the cabling design problem. In this work, we present a set of engineering costs and rules of cabling that take into account the different possible operations on optic fiber cables. For this purpose, we propose combinatorial optimization models which can be used to design either the network between a central office and several equipment (usually optical splitters), or between an equipment and end users. The models are then assessed on real-life instances, along with possible enhancements.

2 - Survivable Regenerator Location Problem
Yash Aneja, Xiangyong Li

In this paper we consider the problem of locating regenerators optimally on certain nodes in an optical network to ensure that all nodes can communicate with each other even when (at most) one edge, of the physical network topology, can fail. The quality of an optical signal propagating through a wavelength division multiple multiplexed (WDM) network deteriorates due to physical layer impairments such as optical noise, chromatic and polarization mode dispersion, cross-phase modulation and cross talk. When the quality of signal becomes unacceptable, it is necessary to carry out the 3R-generation (reamplify, reshape and retime) on the optical signal to bring the signal to its original quality. The optical reach is defined as the maximal distance a signal can travel before it requires the regeneration. Here we study the polyhedral structure of the convex hull of all feasible solutions by providing necessary and sufficient conditions for certain classes of valid inequalities a facet defining. We propose an integer linear programming formulation of the problem that minimizes the number of regenerators needed. We discuss an effective branch-and-cut algorithm for the problem. We also provide an efficient dual ascent algorithm finding find a good feasible solution to the problem.

3 - A Review for the Sustainable Network Security Design Problems
Mehmet İvgin, R. Aykut Arapoglu

In our research we discuss the application of a matheuristic to the leader-follower type of games that occur in the context of discrete location theory. The players of the game are a network designer and an attacker. The decisions of the former are related to locating/relocating facilities as well as protecting some of those to provide service. The attacker, on the other hand, is interested in destroying (interdicting) facilities to cause the maximal possible disruption in service provision or accessibility. The motivation in the presented models is to identify the facilities that are most likely to be targeted by the attacker, and to devise a protection plan to minimize the resulting disruption on coverage as well as median type supply/demand or service networks. These models can be formulated as a bilevel programming problem where the upper and the lower level problems with conflicting objectives belong to the leader and the follower, respectively. Our proposed network design problem will be a triple problem of military facility Location, Protection and Interdiction.

4 - An exact approach for two-level survivable network design problems
Inmaculada Rodríguez Martín, Juan José Salazar González, Hande Yaman

We address the problem of designing a two-level network protected against single-edge failures. The problem simultaneously decides on the partition of the set of nodes into terminals and hubs, the connection of the hubs through a backbone network (first network level), and the assignment of terminals to hubs and their connection through access networks (second network level). We consider two survivable structures in both network levels. One structure is a two-edge connected network, and the other structure is a ring. There is a limit on the number of nodes in each access network, and there are fixed costs associated with the hubs and the access and backbone links. The aim of the problem is to minimize the total cost. We present integer programming formulations and valid inequalities for the different versions of the problem, solve them using a branch-and-cut algorithm, and show computational results.

■ MD-67

Monday, 14:30-16:00 - Livingstone LT210, Level 2

Topics in Combinatorial Optimization II

Stream: Combinatorial Optimization
Invited session
Chair: *Valentina Cacchiani*

1 - Designing and Constructing Networks under Uncertainty: Definition and Exact Algorithmic Approach
Eduardo Álvarez-Miranda, Jordi Pereira

In this work we study a novel Network Optimization problem whose core is to combine both network design and network construction scheduling under uncertainty into a single two-stage robust optimization model. The first-stage decisions correspond to those of a classical network design problem, while the second-stage decisions correspond to those of a network construction scheduling problem (NCS) under uncertainty. The resulting problem, that we will refer to as the Two-Stage Robust Network Design and Construction Problem (2SRNDC), aims at providing a modeling framework in which design decision not only depend on the design costs, e.g., istances, but also on the corresponding construction plan. We provide motivations, mixed integer programming formulations, and exact decomposition algorithms. Experimental results on a large set of instances show the effectiveness of the model for providing robust solutions, and the capability of the proposed algorithm to provide good solutions in reasonable running times.

2 - Solving the List- and Multi-Coloring Variants of Vertex Coloring Using Quadratic Programming.
Patrick Healy

We investigate quadratic programming solutions to the vertex coloring problem and several variants that occur in practice. We demonstrate that several variants of the generic (vertex coloring) problem that arise in practice may be easily implemented as extensions to a quadratic programming (QP) framework for the generic case.

Several variants of the graph coloring problem can be modelled as quadratic unconstrained binary optimization (QUBO) problems. However, we adopt a more general approach, solving the QP subject to box constraints on the model variables. This offers more flexibility in the modelling phase. Embedded in the algorithm is a line-search step and we compare the performances of two line-search algorithms, one based on Newton-Raphson and the other a faster, Armijo-type algorithm, suggesting that the Newton-Raphson algorithm yields superior results.

Since our claims of ease of extensibility can also be made for mixed integer programming (MIP) models we compare the two approaches on both the generic problem and its extensions. Our experiments suggest that as a partial measure to counter the tyranny of symmetric solutions it is more effective to penalise solutions with higher-numbered colors than the alternative strategy of employing additional binary variables that forbid k-colorings comprising colors numbered higher than k. This appears to contradict the conventional wisdom in the MIP arena.

3 - Solving a Mailroom Inserting Machine Planning Problem
Valentina Cacchiani, Andrea Bettinelli, Sandro Bosio

In this paper, we study a real-world planning problem for mailroom inserting machines. A mailroom inserting machine consists of a line with a set of feeders, each one capable of placing an advertising insert into a newspaper passing on the line. The advertising inserts, that need to be bundled in a given number of copies, are grouped into jobs. Each job requires a production time and the mailroom inserting machine can process one job at a time. Loading an insert into a feeder requires a setup time and can only be done if the feeder is idle. Due to the limited number of feeders, in order to respect the setup times, one or more machine stops might be necessary. We are given the job sequence and the corresponding minimum number of machine stops.

The Mailroom Planning Problem (MPP) consists of determining the assignment of advertising inserts to feeders, that minimizes the number of insert splits (i.e. the number of different feeders on which an insert is loaded) and the number of insert loads (i.e. the number of loading operations of inserts into the feeders), while not increasing the given number of machine stops. We present two Integer Linear Programming (ILP) models for MPP, namely a compact one and an ILP model with exponentially many variables. We propose an aggregation scheme to reduce the instance sizes, and a math-heuristic algorithm. Computational results on real-world instances show the effectiveness of the proposed method.

■ MD-69

Monday, 14:30-16:00 - Livingstone LT212, Level 2

Machine Learning and Optimization

Stream: Business Analytics and Intelligent Optimization
Invited session
Chair: *Sebastian Maldonado*

1 - A Profit-based Model Selection Framework for Churn Prediction using Support Vector Machines

Sebastian Maldonado, Álvaro Flores, Thomas Verbraken, Richard Weber, Bart Baesens

Churn prediction is an important application of classification models that identify those customers most likely to attrite based on their respective characteristics described by e.g. socio-demographic and behavioral variables. Since nowadays more and more of such features are captured and stored in the respective computational systems, an appropriate handling of the resulting information overload becomes a highly relevant issue when it comes to build churn prediction models. As a consequence, feature selection is an important step of the respective classifier construction process. Most feature selection techniques; however, are based on statistically inspired validation criteria, which not necessarily lead to models that optimize goals specified by the respective organization. In this work we propose a profit-driven approach for classifier construction and simultaneous variable selection based on Support Vector Machines. Experimental results show that our models outperform conventional techniques for feature selection achieving superior performance with respect to business-related goals.

2 - Multi-class Support Vector Machines using the center of the configuration

Miguel Carrasco, Sebastian Maldonado, Julio López

Multi-class classification is an important pattern recognition task that can be addressed accurately and efficiently by Support Vector Machine (SVM). In this work we present a SVM-based Multi-class classification approach that uses the center of the configuration, a point which is equidistant to all classes. The Multi-class SVM model can be obtained by solving a particular convex quadratic minimization problem. We provide a geometric interpretation of this minimization program by computing the respective Wolfe Dual problem. The center of the configuration is obtained by minimizing the distances between the reduced convex hulls using the euclidean norm, while the decision functions are subsequently constructed from this point. Several extensions of this formulation are presented. For example, the use of L1-Norm which provides a single linear programming formulation; or including chance constraints, which results in a Convex Cone constrained Mathematical Programming problem. Experiments on benchmark data sets are presented for the proposed alternatives.

3 - A Sampling Algorithm for Imbalanced and Overlapped Data

Seongwon Jang, Seung Hwan Park, Jun-Geol Baek

In real-world data sets, class imbalance and overlap problem frequently occurs. The most of machine learning algorithms are more focusing on classification of majority data so that minority data is frequently misclassified. Additionally, data with the imbalanced class distribution contains overlapped regions where some samples from the other class have very similar characteristics. The class overlap problem makes classification task more difficult. To solve these problems, we propose a sampling algorithm for considering the balance of majority and minority data. An imbalance ratio in the overlap region has a more effect on deciding classification boundaries than an overall imbalance ratio. Thus, We separate all data into a "region A' near decision boundaries which includes the class overlap regions and the other "region B'. In the region A, we divide majority-class data into several subgroups by using a clustering algorithm and extract random samples from each subgroup in proportion to its size. At this point, a ratio of the total number of random samples to region A's majority-class data has to be equal to a ratio of the number of overall minority-class data to overall majority-class data. This sampling algorithm is expected to prevent information loss of original data by limiting scope where the samples are extracted. To demonstrate the excellence of our algorithm, we use various type of artificial data and compare with existing methods.

4 - Transfer of semi-supervised manifold learning for efficient sentiment analysis

Jaewook Lee, Saerom Park

Sentiment analysis, which detects the subjectivity or polarity of documents, is one of the fundamental tasks in text data analytics. Recently, the number of documents available online and offline is increasing dramatically, and preprocessed text data have more features. This development makes analysis more complex to be analyzed effectively. This paper proposes a novel algorithm for sentiment visualization and classification that efficiently detects the subjectivity or polarity of text documents available both online and offline. The method first takes a vast size of offline document corpus as input and produces their corresponding continuous word vector representations as output. By transferring such representations to those of online document corpus, the proposed then reduces classification errors of sentiments by removing redundant features effectively via semi-supervised manifold learning techniques. Experimental results suggest that the proposed method can provide not only an efficient way to visualize documents in a low dimensional embedded space, but also a better accuracy in sentiment classification.

■ MD-70

Monday, 14:30-16:00 - Livingstone LT303, Level 3

Operational Research and Decision Making 1

Stream: Operational Research and Decision Making
Invited session
Chair: *Pavankumar Murali*

1 - Markovian decision making models in queuing systems.

Farah Ahmadzada

One of the crucial factors which should be taking into account in the process of making decision is the random factor. One should remark that random factor is not adequate to the uncertainty one because while taking into account "randomness' is necessary that mass phenomena possess property of statistical stability. This implies that random phenomena follow the specific statistical regularity, the requirements of which are not obligate while considering uncertainty. The condition of statistical regularity allows using effective mathematical methods of the stochastic processes theory in the process of making decision, in particular, one of its parts — Theory of Markovian processes. In this paper we consider Markovian decision process models to determine "appropriate' service level in the queuing systems. In these models higher level of service means decreasing waiting time in the system. Functional index of the service system which was obtained earlier for the different models was applied for searching balance between two conflicting factors (service level and waiting time in the system). Analysis of the queuing system models, essentially, doesn't solve problem. It helps to evaluate functional indexes of the service system in order to imply them in some decision process models.

2 - The Use of Fuzzy Approach to Define Risk Acceptance Boundaries

Celina P. Leão, Matilde A. Rodrigues, Eusebio Nunes, Sergio Sousa

Occupational Safety & Health (OSH) practitioners' judgments concerning risk have a great importance in decision-making process. They are essential in the definition of acceptance criteria, as they have the technical knowledge about risks. This paper aims to define acceptance criteria for the specific case of the furniture sector, through the analysis of the OSH practitioners views about the level of risk acceptance (RA)

using Fuzzy Logic approach. The data collected is the result of a RA level questionnaire which included 79 risk scenarios, each accounted for the frequency of an accident with more lost workdays than a given magnitude. Through the two-step cluster analysis three groups of OSH practitioners were identified: Unacceptable, Tolerable and Realistic. A Fuzzy Logic approach is proposed to model the risk judgements of all the three groups. The membership functions of inputs and output variables were determined and the relationship between the variables was mapped through fuzzy rules. Next, the Min—Max fuzzy inference method was used. The results allow to better understand the uncertainty related to the OSH practitioners judgments, being an important step to better know the modelling of judgments about RA level, allowing to discern the different RA levels for the different accident scenarios. The proposed model smoothens the transition between different levels of RA, that reflects the uncertainty in the OSH practitioners RA level and makes the model more realistic.

3 - Sparsity PageRank problem without spectral gap condition
Dmitry Kamzolov, Denis Dmitriev, Anton Anikin

In the PageRank problem we need to find a Perron-Frobenius eigenvector of stochastic n times n - matrix P (where n is of the order one billion). It is assumed, that the maximum number s of nonzero elements on each row and column of this matrix is much smaller than n. We reduce PageRank (due to A. Gasnikov) problem to a quadratic optimization problem. After that we use (due to Yu. Nesterov) a simple gradient descent with 1-norm set up. We show that in this framework we can use sparsity of the problem. The main result, based on Nesterov's technique, is that number of arithmetic operations to find a vector x depends on the square of s and the logarithm of n in direct ratio and the square of epsilon in inverse ratio. We find a vector x satisfying condition that second norm of (Px - x) smaller than epsilon. This estimate improves the current best known results for PageRank problem without spectral gap condition (Gasnikov A., Dmitriev D. // Comp. Math. and Math. Phys. 2015. V. 55. no. 3. P.355-371).

4 - Applying Data Mining Techniques to Direct Marketing: Challenges and Solutions
Pavankumar Murali, Ying Li, Anshul Sheopuri

We address one of the most common tasks faced by marketers when faced with resource and time constraints,namely, consumer prioritization with the objective of optimizing one or more marketing key performance indicators such as consumer conversion. A key element in building predictive models is the ability to introduce features that capture historical user behavior in an effective manner so as to identify those consumers who are most likely to convert with or without nurturing, and those who are unlikely to convert irrespective of the marketing campaign and channel. We propose to use a set of dynamic features to capture consumers' engagement behaviors. We have also applied the non-negative matrix factorization (NMF) to identify certain hidden customer behavior patterns and use them as additional features. Various sampling techniques are then explored and compared to address the following three most common challenges faced in dealing with marketing data: 1) severely unbalanced historical ground truth; 2) sparsity in the relevant data due to low historical response rates; and 3) high dimensional due to the large variety of campaign channels, programs or themes. To validate our approach, we have conducted some preliminary experiments using real-world campaign data. The evaluation shows that the random oversampling approach has the best performance giving the largest area under the curve (AUC) and an up to 160% improvement in the lift index.

■ MD-71
Monday, 14:30-16:00 - Livingstone LT307, Level 3

Graphs and Networks A

Stream: Graphs and Networks
Invited session
Chair: *Reinhardt Euler*
Chair: *Tahar Kechadi*

1 - Using an Old Theorem to Cut Out a Lot of Clutter
Gautam Appa, Reinhardt Euler, Anastasia Kouvela, Yiannis Mourtos, Dimitrios Magos, Alex Tran

Mann (1944) gave conditions under which a Latin Square L1 of dimension 4n+2 cannot have an orthogonal mate L2. These relate to the no. of cells with digits other than 1 to 2n+1 in the sub-square formed by the first 2n+1 rows and columns of L1. We show that if judiciously used, this theorem can provide an alternative proof of the non-existence of an orthogonal pair of size 6. The approach leads to promising new directions for the open problem of the existence of 3 MOLS of size 10.

2 - Finding a Polygon Hull in Wireless Sensor Networks
Ahcene Bounceur, Reinhardt Euler, Ali Benzerbadj, Farid Lalem, Massinissa Saoudi, Tahar Kechadi, Marc Sevaux

Finding the border of a wireless sensor network (WSN) is one of the most important issues today. This border can be used, for example, to monitor a frontier or a secured place of sensitive sites of a country. One of the methods that can be useful for this kind of problems is Jarvis' algorithm which has to be adapted to take account of connected nodes in a Euclidean graph. For this kind of networks, the complexity is reduced from O(nh) to O(kh2), where n is the number of sensors, k is the maximum number of neighbors of a sensor in the network and h is the number of sensors of the envelope. The application of this algorithm to WSNs allows in each iteration to determine the next boundary neighbor of the current node. The advantage of this procedure is that each node knows its neighbor in a single operation. Then, each boundary node will periodically send a message to its neighbor, which should respond. If a response is not received, a situation of failure or intrusion will be triggered and network restructuring will be launched to find a new border. In this work, we have shown that the application of this algorithm in the presence of sub-absorbent graphs can lead to an infinite loop situation. We have also shown how to overcome this situation and how the algorithm can be applied to the case of WSNs.

3 - On the Connected Spanning Cubic Subgraph Problem
Damien Massé, Reinhardt Euler, Laurent Lemarchand

Given a distance matrix D, the connected spanning cubic subgraph problem (CSC) is to determine a connected cubic graph minimizing the total distance. Restricting matrix D to have 0-1 entries only leads to the problem of deciding whether a given graph contains a connected spanning cubic subgraph. We present some first results on the facial structure of the associated polytope including several classes of valid inequalities some of which are shown to be facet-defining. To solve problem CSC, two procedures are formulated: the first is based on a binary linear program, that iteratively constructs an optimal solution, the second on a linear program, that iteratively exploits additional cutting planes from different families to accelerate the solution process. All formulations have been implemented and tested on series of randomly generated problem instances.

■ MD-72
Monday, 14:30-16:00 - Livingstone LT311, Level 3

Discrete and Global Optimization 2

Stream: Discrete and Global Optimization
Invited session
Chair: *Jan van Vuuren*

1 - A Test of Integer Linear Programming Formulations for the Closest String Problem
Claudio Arbib, Mara Servilio, Paolo Ventura

Recently, integer linear programming (ILP) formulations have been successfully applied within effective heuristics for the Closest String Problem (CSP). We consider two ILPs for the binary and general (nonbinary) CSP that improve previous ones, and solve them by Branch and Cut. Our method uses the first closure of Chvàtal-Gomory cuts, that we prove separable in polynomial time in the binary case. The method can either be used stand-alone to find optimal solutions, or as a plug-in to improve the performance of heuristics that require the exact solution of reduced problems.

2 - Finding Zero-One Combinations Related to Success in e-commerce
Arik Sadeh

In e-commerce there is a motivation to convince potential buyers to enter a given e-shop. The study aimed to figure out what combinations of factors lead to success of these e-shops. Each factor has two levels: low and high. Success is marked when a consumer decides to buy from that shop. The study includes a survey among potential buyers. The results of the survey are used to identify the frequency of combinations of the most important factors that lead to better success. This is done using binary mathematical programming. There are common procedures to find those combinations. An efficient algorithm is suggested to take in account effective aspects of those combinations.

3 - The Proximity r-Gathering Problem
Shin-ichi Nakano

In this paper, we study a recently proposed variant of the problem, called the r-gathering problem. Given a set C of customers, a set F of facilities, and a connecting cost co(c,f) for each pair of c in C and f in F, then the r-gathering problem is to choose a subset F' in F of facilities and find an assignment A from C to F' so that the maximum cost is minimized. The proximity r-gathering problem finds an assignment with one more additional constraint, that is each customer should be assigned to a closest open facility. Armon gave a 9-approximation algorithm for the problem. In our paper, we present a simple 3-approximation algorithm for the proximity r-gathering problem.

4 - A Comparison of Exact Approaches to the Job Sequencing and Tool Switching Problem
Martin Kidd

The job sequencing and tool switching problem comprises a set of jobs to be performed on a machine, a set of tools required to perform each job, and a magazine with a maximum capacity into which tools are loaded. The tool sets required by any two jobs may intersect, and the objective is to find a sequence of the jobs and assignments of tools to the magazine such that the total number of tool switches that needs to be performed between jobs is minimized. A number of integer linear programming formulations are reviewed from the literature, and exact approaches based on branch and bound and dynamic programming are compared using benchmark instances from the literature. For instances where the exact methods become intractable, investigation is done towards partitioning the problem into subproblems that are sequentially solved to optimality.

■ MD-73

Monday, 14:30-16:00 - Collins CL205, Level 2

Forecasting - General Session

Stream: Forecasting & Time Series Prediction
Invited session
Chair: *Aris Syntetos*

1 - Nowcasting of gross regional product and analyzing regional business cycles
Nariyasu Yamasawa

This study attempt to analyze the relationships between the prefectures' business cycles in Japan. There are many studies about business cycle synchronization in Europe and East Asia. We apply country level analysis to prefecture-level. First, we attempt to estimate monthly real Gross Regional Product (GRP) for 47 prefectures in Japan. It enables us to investigate the present condition of regional economy. The official annual GRP is published late. It is published two years after the concerned period. Our real monthly GRP is published two months later after the concerned period. We estimate it by various monthly data and using panel data estimation technique. Second, we extract business cycles from real monthly GRP by band pass filter. We consider that we should remove shorter cycle series (noise) and longer cycle series (trend) in order to investigate a pure relationship of business cycles between prefectures. Third, we investigate lead-lag relationship between prefectures' business cycles. We found that prefectures' business cycle differ significantly. Further, we investigate spatial relationship between prefectures' business cycles. These results help us to forecast prefectures' business cycles.

2 - Causal leading indicators detection for demand forecasting
Yves R. Sagaert, Nikolaos Kourentzes, El-Houssaine Aghezzaf, Bram Desmet

Demand forecasts are often univariate, or include only limited causal promotional information on a short-term horizon, which do not capture changing long-term global markets. More especially, including causal exogenous information in the forecasting models could enrich the long-term forecast. The limited historical data is typically used to both identify the current univariate structure and select the appropriate causal leading indicators from a large set of exogenous variables. A key challenge is to be able to distinguish between correlated and causal variables. The resulting variable selection problem is well studied in literature, but far from resolved. Furthermore, the problem gets harder by the limited available historical data in this context of business forecasting. The amount of historical sales observations is far less than the size of the pool of potential causal leading indicators. Methodologies from heuristics to shrinkage estimators, such as LASSO, are examined to overcome the variable selection problem. In a case study, we use real demand data from a global manufacturer and potential causal leading macro-economic indicators from the different global markets the manufacturer trades in.

3 - Time series analysis of the number of road motor vehicles in Turley
Kadir Berkhan Akalın, Murat Karacasu, Barış Ergül, Arzu Altın Yavuz

Recently there has been an increased interest in number of motor vehicles in Turkey. Number of road motor vehicles in Turkey is increasing at an alarming rate and has raised major concerns. There is a feeling that the rapid growth of traffic should be accompanied by additional efforts to improve traffic safety, in order to stop the corresponding increase in number of road motor vehicles. In this study the developments of traffic and number of road vehicles are investigated and forecasts are made. Time series with Box — Jenkins method was applied to 47 years of annual number of road motor vehicles data from 1966 to 2013 to determine patterns of road traffic safety cases. Models were subsequently developed for number of road motor vehicles in Turkey. ARIMA(0,2,1) was used to model the number of road vehicles data from 1966 to 2013. Model showed that number of road motor vehicles in Turkey would continue to increase.

■ MD-77

Monday, 14:30-16:00 - Collins Insight Institute

Behavioural Issues in Decision Analysis I

Stream: Behavioural Operational Research
Invited session
Chair: *Gilberto Montibeller*

1 - Path dependence in operational research: An illustration with the even swaps decision analysis method
Tuomas Lahtinen, Raimo P. Hämäläinen

In OR a path refers to the sequence of steps that are taken in the problem solving process. The steps can include the framing and structuring of the problem, the order in which different parts of the model are built and the way in which data or preferences are collected. We identify and discuss six types of origins for path dependence: structure, uncertainty, procedure, behavior, motivation and external origins.

Path dependence is a concept discussed earlier in economics, policy studies, sociology, and organizational decision making. The current state of the world is a consequence of the path taken, i.e. history matters. The lock-in phenomenon which refers to strong anchor points from which it is not easy to move forward represents one kind of path dependence.

Our key message is that in OR we should pay more attention to the modeling process and interaction with the stakeholders. Different modeling processes can elicit different behavioral effects which can cause the outcome to depend on the path. In addition, we should be aware of the risk of getting anchored into one particular modeling approach. For example, groupthink can reinforce the belief of the superiority of the models currently in use.

We demonstrate experimentally how path dependence emerges in the Even Swaps decision analysis method. We explain the results by the accumulation of two known biases, loss aversion and scale compatibility. A strategy to reduce the accumulation of these biases is suggested.

2 - Behavioural analytics: exploring behavioral patterns in large data sets
Ian Durbach, Gilberto Montibeller

The ever-increasing availability of large data sets that store users' judgments and choices provides exciting opportunities for decision science. We discuss ways in which established fields of behavioral decision research (BDR) might be valuable for organizations as a means of detecting behavioral patterns, exploiting behavioral biases, and improving judgments and decisions. We illustrate how BDR and analytics can be meaningfully integrated with three real-world studies drawn from sport predictions and online gaming applications.

3 - Understanding the challenges of decision-analytic interventions in organisations – a practice-based framework
Kai Helge Becker, Ana Barcus

Decision Analysis has made remarkable and exciting progress in improving decision making in organizations, providing a sound prescriptive approach for the evaluation of decision alternatives. However, as decision analysts know from experience, applying the methods in real-life organisational interventions often turns out to be challenging. Our paper contends that these difficulties are the consequence of a gap between the prescriptive approach of Decision Analysis and the way in which unsupported decision making is typically carried out in organizations. Moreover, we argue that decision analysts tend to systematically underestimate the width of this gap due to implicit assumptions about how decision making is carried out in practice. Based on a sociological strand of theorizing called "theories of social practices", we present an empirically supported framework that (i) describes the nature of this gap and (ii) provides a systematic explanation of the challenges that decision analytic interventions have to cope with. In this way, the paper contributes to a deeper understanding of the behavioural aspects of DA interventions and offers a means to reflect on the challenges frequently experienced by decision analysts, which may guide the further development of decision aiding methods.

4 - Biases and Debiasing in Risk and Decision Analysis Modelling
Gilberto Montibeller, Detlof von Winterfeldt

Behavioral decision research has demonstrated that judgments and decisions of ordinary people and experts are subject to numerous biases. Decision and risk analysis were designed to improve judgments and decisions and to overcome many of these biases. However, when eliciting model components and parameters from decision-makers or experts, analysts often face the very biases they are trying to help overcome. When these inputs are biased they can seriously reduce the quality of the model and resulting analysis. Some of these biases are due to faulty cognitive processes; some are due to motivations for preferred analysis outcomes. In this talk we identify the cognitive and motivational biases that are relevant for decision and risk analysis, because they can distort analysis inputs and are difficult to correct. We also review and provide guidance about the existing debiasing techniques to overcome these biases. In addition, we describe some biases that are less relevant, because they can be corrected by using logic or decomposing the elicitation task. We conclude the talk discussing recent developments in the efficacy assessment of debiasing tools.

■ MD-78
Monday, 14:30-16:00 - Architecture AR201, Level 2

Dynamic Games in Economics

Stream: Dynamic Models in Game Theory
Invited session
Chair: *Suresh Sethi*

1 - Pollution control in a multiregional setting: A differential game with spatially distributed controls
Guiomar Martin-Herran, Javier de Frutos

We analyze differential game models where pollution control is spatially distributed among a number, possibly large, of agents with predetermined spatial relationships. The analysis emphasizes the effects that could be expected as a consequence of the different geographical relationships among decision makers. The game has one state variable (pollution stock) distributed among one large region divided in subregions which control their own emissions of pollutants. The emissions are also represented as a distributed variable. The dynamics of the state variable is defined by a parabolic PDE.

2 - Duopolistic competition and innovation with an endogenous hazard rate
Michel Keoula, Herbert Dawid, Michael Kopel, Peter M. Kort

We employ a dynamic duopoly game with evolving demand structure to study the interplay between product innovation activities of the firms and their investments in production capacities for an established product. A four-mode differential game is considered. In the first mode, both firms invest in production capacities for the established product and in their respective R&D stock. For each firm, the hazard rate of the innovation depends on that stock and on current R&D investment. Innovation by any of the players moves the game in one of two symmetric modes where only the leader in innovation offers both products and invests in production capacities for both of them. The laggard keeps investing in R&D and capacities for the old product. In the fourth mode, both firms offer both products and invest in their respective capacities. Markov perfect equilibria are characterized using a numerical approach based on the Smolyak collocation method.

Under Markov-perfect equilibrium behavior the firm with higher share in the established market is less likely to be the first innovator. A firm's innovation activity is negatively affected by the opponent's capacity on the established market as long as the opponent has not innovated yet, but this effect is reversed after the opponent's innovation breakthrough. There is a positive relationship between concentration on the established market and innovation activities.

3 - 5 Steps to Supply Chain Coordination
Suresh Sethi

There has accumulated a considerable literature on supply chain coordination over the last two decades. In single period cases, most papers carry out the following four steps: 1. Solve the given decentralized problem; 2. Solve the corresponding centralized problem; 3. Show that there is double marginalization and hence the need for coordination; 4. Obtain a contract to coordinate the supply chain. The coordinating contract is obtained by equating the follower's best response to the centralized channel's optimal decision. A missing step is to show that the coordinating contract so obtained is an equilibrium in the Stackelberg game under the contract. In this paper, we present this missing step (the 5th step) by showing that the coordinating contract obtained in the conventional way is indeed a Stackelberg equilibrium. We develop a general framework to obtain coordinating contracts and apply it to special cases, such as revenue-sharing contract, buy-back contract, quantity flexibility contract, and sales rebate contract. We conclude the paper by extending the 5-step approach to two-period supply chains where the equilibrium concept to be used is that of Feedback Stackelberg equilibrium.

■ MD-79
Monday, 14:30-16:00 - Architecture AR310, Level 3

Simulation in Health Care

Stream: Simulation in Health Care
Invited session
Chair: *Salma Chahed*
Chair: *Philip Worrall*

1 - Toward Simulating the English Local Neonatal Unit
Sarah Dalton, Salma Chahed, Thierry Chausselet

The United Kingdom (UK) National Health Service (NHS) is widely acknowledged to have systems problems. Studying access to such assets as specialised care allows flexing of nurse staffing to meet certain patient demand and lessens capacity transfers, many of which were seen this winter and can be hard to manage. Strict nurse: baby ratios are laid down for British neonatal dependency, whether intensive care, high dependency or special care. Unless extremely premature, patient centred care favours flexing staff to nurse the patient nearest

home rather than the delay, risk and resources of transferring a sick patient miles elsewhere. Such questions as the risk/certainty and duration of a bottleneck in flow might arise in operational practice and inform business continuity planning and financial forecasting. The proposed model might be developed to allow timely prediction of need for increased nurse staffing and external support, load balancing within the greater perinatal network and improved efficiency. Routinely available data were obtained from Hospital Episode Statistics (HES) and Standardised Electronic Neonatal Database (SEND) and included items such as gestation, length of stay at the three care levels and movements between them. Simulation outputs such as cot utilisation, queueing and proportion of time for which the system was over-subscribed and baulked, were analysed and a set of recommendations drawn up.

2 - Living with Multiple Long Term Conditions — Testing the Impact of a Capitated Annual Payment using Simulation

Jamie Day, Claire Cordeaux, Beverley Matthews

More people are living with multiple long term conditions than they are with one disease but services tend to be organised by single disease groups. NHS Improving Quality wanted to test the impact of applying an annual capitated budget for people in this group to facilitate better joint working across organisations and departments to better meet the needs of these patients.

Working with 5 Early Implementer sites across England with representation from health and social care payers and providers, 2 consecutive years of health and social care resource utilisation data was collected from a cohort of 550 individuals with 2 or more long term conditions. Analysis by risk score against annual cost of services used by individual patients was not able to segment patients into possible cost bandings. When risk scores were supplemented with data on numbers of long term condition, patient groups in broad cost bands could be identified. This enabled sites to proactively identify and manage patients.

The sites simulated the impact of applying an annual tariff to cohorts of patients, replicating the use of services by patient group (including likelihood of transition between groups) and enabling payers and providers to test any changes in their care model.

The session will outline how the experience of the Early Implementer Sites informed the simulation and how the simulation in its turn is driving adoption of best practice.

3 - Work-force Planning Inside and Outside the Operating Room: a Simulation Approach

Jane Despatin, Michel Nakhla

The operating room represents a major hospital cost centre and a highly technical area in hospitals. Thus, it is of high interest for human resource management (Guerriero 2011, Butler 1996). Simulations of the surgical process from a human resources perspective are numerous in the literature. However, activities performed outside the operating room (i.e. "external activities') are generally neglected (Blake and Carter 1996, Sobolev, Sanchez, and Vasilakis 2011). Our contribution aims to fill this gap and answer the following research question: what is the impact of external activities planning on surgical activity? The methodology used in this article is a discrete event simulation of both the surgical process and external activities. We apply our model to a case study of three French military hospitals with 20 months of historical data. In this case, external activities are military missions conducted abroad. Medical and paramedical staffs are both involved in the missions. The simulation evaluates the impact of external activities on the volume of surgical care delivered and the number of wasted working hours in the operating suite. Our study shows that external activities often destabilise the surgical process, lowering the operating room efficiency. A global vision of staff activity can be gained through simulation. Critical resources are identified and simulation can be used as a decision support tool for tactical human resource planning in the operating room.

4 - Mathematical Optimization and Simulation Analyses for Optimal Liver Allocation Boundaries

Naoru Koizumi, Debasree DasGupta

Geographic disparity in transplant access is a persistent issue ever since organ allocation became a regulated process in 1984. While several changes in allocation rules have been introduced to address the disparities, transplant researchers still report that a number of key elements that determine equity in transplantation vary significantly depending on the location of a patient. Our study developed a mathematical programming model to redesign liver allocation boundaries. The optimal boundaries were derived to maximize efficiency and geographic equity in access to liver transplantation. Part of this mathematical model also analyzed optimal locations for liver transplant centers. To evaluate the performance of the optimal boundaries in a realistic setting, we developed a discrete event simulation model that reflects the actual liver—candidate matching and the actual liver allocation protocols practiced until 2013. Our results confirmed that the mathematically driven optimal boundaries could reduce average waiting time and graft transfer distance, and could increase access to transplant across regions. Further, the average organ transfer distances for all analyzed cases were shorter than that under the current system.

■ MD-80

Monday, 14:30-16:00 - Architecture AR311, Level 3

Maritime Transportation

Stream: Transportation Planning
Invited session
Chair: *Frank Meisel*

1 - Vessel Speed Optimization Problem in Liner Shipping with Stochastic Port Times

Nursen Aydin, Afshin Mansouri, Habin Lee

Recent studies in maritime shipping have concentrated both on environmental and economic impacts of container ships and fuel consumption is considered as one of the important factors for such impacts. In particular, the sailing speed of the vessels affects the fuel consumption directly. In this study, we consider a speed optimization problem in liner shipping with stochastic port times. The objective is to minimize the total fuel consumption by considering service level. We develop a dynamic programming model by discretizing the port arrival times to provide approximate solutions. A deterministic model is presented to provide a lower bound on the optimal expected cost of the main dynamic model. Our numerical study using real data indicates that the proposed dynamic programming model performs well. Moreover, our results show that making speed decisions considering the uncertainty of port times will noticeably decrease fuel consumption cost.

2 - Investment into ocean freight capacity: A real options approach in oligopolistic competition

Philipp Rau, Stefan Spinler

The shipping industry is characterized by cyclicality and strong ordering has led to overcapacity and margin erosion in the past years. Since the industry is complex and has specificities we develop an industry-specific investment model with the use of real options theory in oligopolistic competition. The problem at hand is solved with two models: an analytical formulation of the problem with a closed-form solution (investment trigger) and a numerical extension for three strategic firms. Among others, we investigate effects of competition, fuel efficiency, and volatility to derive managerial implications. We find that strategic action (as opposed to being a myopic player) pays off and argue that it is worthwhile to consider alliances from an investment standpoint. Players in the market should consider retrofitting old vessels for better fuel economy in economic downturns and use new, fuel efficient vessels for capacity expansion in market upswings while keeping fleet sizing strategy sufficiently flexible.

■ MD-82

Monday, 14:30-16:00 - Architecture AR401b, Level 4

Health Care Analytics

Stream: Healthcare Service Improvement
Invited session
Chair: *Annette van der Merwe*

1 - ERP Performance Improvement in Nuclear Pharmaceuticals Manufacturing

Ozay Ozaydin, Mert Bilal BiÇakci, Seyhan Tilbaç, Nesi Zakuta, Duygu Altay

Nuclear medicine is a medical specialty involving the application of radioactive substances in the diagnosis and treatment of disease, and half-life is a crucial characteristic of the before-mentioned radioactive substances. Briefly, half-life is defined as the time required, probabilistically, for half of the unstable, radioactive atoms in a sample to undergo radioactive decay. This characteristic makes materials requirement planning highly time sensitive. In this study, a case for a nuclear medicine manufacturer in Turkey, where the total healthcare spending per capita increased more than 30% in the last decade, surpassing even the GDP per Capita indicator, is taken into consideration. A dynamic forecasting model integrating classic methods is utilized for various types of medicine used countrywide. A mixed-forecast enabled the manufacturer to implement various strategies for procurement and lower not only stock-outs but also unnecessary warehousing costs. The performance of the model is tested by a what-if scenario analysis.

2 - Identifying the Key Success Factors of Adopting RFID System in Nursing Care Service.

Rouwen Wang, *Chao Chan Wu*, *Dong Shang Chang*

Due to the ageing population, the older people need the nursing care to maintain their quality of life. The shortage of workforce results in serious impacts on nursing care service. Applications of intelligent technologies have been widely implemented in practices, such as Radio Frequency Identification (RFID) system. This study focuses on identifying the key success factors for adopting RFID system to improve nursing care service in community. The evaluation approach is integrated with the modified Delphi method, the Decision Making Trial and Evaluation Laboratory (DEMATEL), and the Analytic Network Process (ANP). There are five perspectives are taken into the questionnaire of evaluation, including environment, organization, skill, cost and society. The questionnaire was assessed by 14 experts and practitioners. The results reveal that increasing reliability of vendors' technology, decreasing the setup cost and system integration cost, improving collaboration of inter-organization and enhancing customer satisfaction are identified as key success factors. These factors are useful in implementing the RFID system of nursing care service.

3 - Finding the best emergency care facility for stroke patients

Annette van der Merwe, *Phillip Benade*, *Hennie Kruger*

Acute strokes are emergency events which need to be treated as soon as possible, preferably within a maximum of three hours of onset. Such treatment should only be governed in specialised treatment units so that the time it takes for a patient to be diagnosed and to receive the care needed, is minimised. In South Africa however, units capable of correctly diagnosing and treating stroke patients are not readily available meaning certain factors need to be considered when deciding where the patient needs to go. A computer application, using expert system principals in combination with mathematical modelling, is being developed to determine the best treatment unit for a patient who could've suffered from a stroke and to use the patient's location as well as the location of the nearest available emergency care units to determine the optimal unit for that particular patient.

■ MD-84

Monday, 14:30-16:00 - Architecture AR403, Level 4

Protein Bioinformatics

Stream: Computational Biology, Bioinformatics and Medicine
Invited session
Chair: *Piotr Lukasiak*

1 - Progress in NVR for NMR Structure-Based Assignments

Mehmet Serkan Apaydin, *Şeyma Çetinkaya*, *Seyma Nur Ekren*

Nuclear Magnetic Resonance (NMR) Spectroscopy is an important technique to obtain structural information of a protein. In this technique, an essential step is the backbone resonance assignment and Structure Based Assignment (SBA) aims to solve this problem with the help of a template structure. NVR is an NMR protein SBA program, that takes as input N15 and H chemical shifts and unambiguous NOEs, as well as RDCs, HD-exchange and TOCSY data. NVR does

not utilize C13 chemical shifts although this data is widely available for many proteins. In addition, NVR is a proof-of-principle approach and has been run with specific and manually set parameters for some proteins. NA-NVR-ACO[1] remedies this problem for the NOE data and standardizes NOE usage. In this paper, we standardize NVR's scoring function by using the same parameters for all the proteins and incorporating C13 chemical shifts. We also use a larger protein database and a state-of-the-art chemical shift prediction tool, SHIFTX2, to extract the chemical shift statistics. Other practical improvements include automatizing data file preparation and obtaining a degree of reliability for individual peak-amino acid assignments. Our results show that our improvements bring NVR closer to a practical tool, able to handle a variety of different data types.

2 - An NK Landscape Based Model Mimicking the Protein Inverse Folding Problem

Sune Nielsen, *Gregoire Danoy*, *El-Ghazali Talbi*, *Pascal Bouvry*

This work introduces a new NK Landscape based model instance designed to mimic the properties of one challenging problem in biology: the Inverse Folding Problem (IFP). Protein structure prediction is an essential step in understanding the molecular mechanisms of living cells with widespread application in biotechnology and health. Given a protein as reference and its corresponding tertiary (3D) structure, the IFP consists in finding RNA sequences which produce very similar 3D structures.In this work an IFP model previously developed to match a neural network secondary structure prediction with a reference, is used. Numerous landscape analysis tests of a problem instance based on the protein 1b3a are conducted. The results are then used to parameterise the new model - a combination of two NK Models, with different K and neighborhood definitions. The model can accumulate the characteristics of both its underlying NK Models to match the epistatic interactions and landscape walk features of the IFP. This work is an initial step in the creation of a fast benchmark for all algorithms targeting protein sequence optimisation. With a simple definition based on the well-known NKModel, the motivation is to make the IFP problem more accessible to optimisation specialists and model experts.Furthermore the statistical nature of the NK Model may provide the ground for a theoretical estimate on the number of protein sequences which fold into a given protein structure.

3 - Combinatorial Methods for RNA and Protein Molecule Evaluation

Piotr Lukasiak

RNAs and proteins are the most important molecules from a biological and medical point of view, since they are involved in a wide range of biochemical reactions in the cells. The activity of mentioned biomolecules strongly dependent on its 3D structure because the structural shape is crucial to investigate the function of a particular residue. Various experimental methods, such as X-ray crystallography, nuclear magnetic resonance or small-angle X-ray have been applied to determine 3D RNA structure. Unfortunately, experimental determination of a high-resolution 3D RNA structure is often difficult, time consuming and expensive. Thus, several computational methods to predict RNA 3D structure have been introduced. 3D models generated by various approaches, often differ significantly between each other, and the decision which one is the native-like becomes a crucial point for researchers. It should be emphasized that the number of RNA 3D models submitted for the contest is growing rapidly, thus it is difficult and time-consuming to assess them and discriminate the most suitable one for analyzed target manually. The quality evaluation of models in the context of the reference structure can be performed in various ways using a wide range of measures. Artificial RNA 3D structures are most often evaluated by numerical or graphical measures. We examined currently available ones and introduced new ideas grew from OR area that are successfully applied in bioinformatics.

Monday, 16:30-17:30

■ ME-01
Monday, 16:30-17:30 - Barony Great Hall

Plenary Lecture: Ralph Tyrell Rockafellar (IFORS Distinguished Lecturer)

Stream: Plenary, Keynote and Tutorial Sessions
Plenary session
Chair: *David Pisinger*

1 - Risk and Reliability in Stochastic Optimization
Terry Rockafellar

Problems of optimization are concerned with making decisions "optimally" however in many situations in management, finance and engineering, decisions have to be made without knowing fully how they will play out in the future. When the future is modeled probabilistically, this leads to stochastic optimization, yet the formulation of objectives and constraints can be far from obvious. A future cost or hazard variable may be a random variable which a present decision can influence to some extent, but maybe only in shaping its distribution in a limited way. For instance, it may be desirable to keep a hazard below a particular threshold, like building a bridge to resist earthquakes and floods, and yet it may be impossible or too expensive to guarantee that the threshold will never be breached.

One needs to have a standard according to which a cost or hazard is "adequately" below the desired threshold in line with its probability distribution. That is the role for so-called "measures of risk," which started to be developed for purposes like assessing the solvency of banks but now are being utilized much more widely. Measures of risk also offer fresh ways of dealing with reliability constraints, such as have traditionally been imposed in engineering in terms of bounds on the probability of failure of various manufactured components. Probability of failure has troubling mathematical behavior in an optimization environment. Now, though, there is a substitute, called buffered probability of failure, which makes better sense and is much easier to work with computationally.

Tuesday, 8:30-10:00

■ TA-01

Tuesday, 8:30-10:00 - Barony Great Hall

Keynote Lecture: Tony O'Connor

Stream: Plenary, Keynote and Tutorial Sessions
Keynote session
Chair: *Valerie Belton*

1 - OR at the Heart of Government - how the Government OR Service Influences Decision Making
Tony O'Connor

In the UK Government the use of analysis and evidence is well established and Operational Research plays an important role alongside the more traditional analytical disciplines of Economics, Statistics and Social Research. This key note address will set out the context in which the Government Operational Research Service (GORS) operates, our role in different departments, showcase some successes and discuss some of the challenges we face. How do we work with ministers? How do we shape their policies and improve the delivery of public services?

It will draw upon personal experiences from various Government departments (including my time as the Chief Analyst to the Prime Minister's Delivery Unit). In addition it will showcase examples from other departments where OR has shaped the decision making of public services both in terms of policy design and operational delivery.

■ TA-02

Tuesday, 8:30-10:00 - Barony Bicentenary Hall

ROADEF/EURO OR Challenge presentation (II)

Stream: EURO Awards and Journals
Invited session
Chair: *Marc Sevaux*

1 - ROADEF OR Challenge presentation : Inventory Routing Problem at a glance with Air Liquide
Michele Quattrone, Jean André, Eric Bourreau, Marc Sevaux

The French OR Society (ROADEF) along with EURO, organizes periodically an OR challenge dedicated to industrial applications. This year, the challenge subject will be proposed by and industrial partner (AirLiquide) and will concern an Inventory Routing Problem. The challenge is open to everyone, and particularly to young researchers. The challenge problematic will be presented during this EURO 2015 and the results will be announced at EURO 2016 in Poznan. A prize of 20000 Euros will be awarded to the best teams. Contact: challenge@roadef.org

■ TA-03

Tuesday, 8:30-10:00 - TIC Auditorium A, Level 2

MAI: Academic-practitioner bazaar

Stream: Making An Impact 1 (MAI 1)
Invited session
Chair: *Jane Parkin*
Chair: *Galina Andreeva*

1 - Academic-practitioner bazaar

This 90-minute session will feature posters and 60-second presentations highlighting the latest developments across the academic-practitioner interface. It will include posters describing problems being worked on, challenges which could be solved by closer academic-practitioner partnership, and showcasing successful examples of ac-prac collaboration. The aim is to have a forum for academic-practitioner interfacing which should help practitioners to enhance their currently used methods by drawing on academic expertise, and academics to ensure their research is shared beyond traditional audiences and used in the most effective way outside academia. A list of posters and presenters will be available on the euro2015.org/MAI pages nearer the date.

■ TA-04

Tuesday, 8:30-10:00 - TIC Auditorium B, Level 2

Retail Supply Chain Management I

Stream: Demand and Supply in Retail and Consumer Goods
Invited session
Chair: *Stefan Minner*

1 - Data-driven Assignment of Delivery Patterns with Handling Effort Considerations in Retail
Florian Taube, Stefan Minner

Focusing on the situation at a European retailer, we consider a supply chain with one warehouse and several stores, where demand is stochastic and non-stationary. Manual processes of order picking at the warehouse and shelf stacking from the store's backroom into shelves are considered. We determine robust delivery patterns and order-up-to levels, which remain fixed for a certain time. Our approach extends the joint replenishment problem with time-varying deterministic demand by a stochastic distribution-free solution approach that optimizes based on multiple historical replications of the target time horizon (e.g. several weeks). By doing so, we include the non-stationary stochastic demand prevalent in retail and use 'Big Data' as direct input for optimization. We introduce a mixed integer linear program and to reduce complexity for large-scale instances, perform a hierarchical decomposition, where the first-stage problem creates delivery patterns and the second-stage problem assigns patterns to products and stores and determines order-up-to levels. For the pattern creation problem we introduce decomposition approaches and a genetic algorithm. In a numerical study, we first compare the approaches on randomly created instances against the classic JRPDD on expected demand values. Results show that costs are cut on average by 2-14 %. We also apply the decomposition approaches on point-of-sales data of the European retailer, where a cost benefit of up to 25 % is achieved.

2 - Delivery Pattern and Transportation Planning in Grocery Retailing
Andreas Holzapfel, Alexander Hübner, Heinrich Kuhn, Michael Sternbeck

We develop a planning concept for defining repetitive delivery patterns according to which stores of a grocery retailer are supplied from a distribution center. Applying repetitive delivery patterns offers major advantages when it comes to scheduling the workforce for shelf replenishment, defining cyclic transportation routes and managing warehouse capacities. In doing so, all logistics subsystems of a retail chain, i.e., warehousing, transportation and instore logistics, are jointly scheduled. We propose a novel model to minimize total costs in all associated subsystems of a retail distribution chain. A solution approach is developed for clustering stores and selecting delivery patterns, which reflects practical requirements. A broad numerical analysis demonstrates cost savings of 2.5% on average. The considerable cost reduction potential is confirmed by applying the suggested approach to a real case of a major European grocery retailer.

3 - An Optimization-Simulation Approach for Warehouse Distribution Master Planning
Sara Martins, Eduardo Curcio, Pedro Amorim, Luis Guimarães, Bernardo Almada-Lobo

Large food retailers have to deal with a complex distribution network with multiple distribution centers, different temperature requirements,

and a vast range of store formats. In this setting, decisions about fleet sizing (types and dimensions), product delivery modes planning (direct shipping and/or hub-and-spoke) and product-warehouse-outlet assignment (assignment to distribution centers) are rather intertwined and solving them separately results in an oversimplification.

In this talk we show how a hybrid optimization-simulation approach may be used to solve this complex distribution problem, which tackles simultaneously the aforementioned decisions. In order to validate the approach data from a major food retailer is used.

4 - A Two-Agent Model for Production and Outbound Distribution Scheduling

Sonja Rohmer, Anthony Brain, Pierre-Antoine Morin, Jean-Charles Billaut

This research aims to propose an integrated model for a three-stage supply chain scheduling problem with a manufacturer, a 3PL-provider and customers, providing decision support at the operational level. The model includes multiple costs such as inventory, transportation and tardiness penalty costs. Two kinds of inventory are considered in the model: work in progress (WIP) inventory and finished product inventory. The problem is viewed as a multi-agent problem that consists of two sub-problems: a permutation flow-shop scheduling problem for the manufacturer and a vehicle routing problem for the 3PL provider. In the integrated approach suggested in this study, the manufacturer and the 3PL provider are both independent agents that cooperate by negotiating the number of vehicles available and the maximum delay for delivery, aiming to optimise their individual schedule. The general framework is presented, Integer Linear Programming models are proposed and the first results show the interest of the models for decreasing the costs of both the manufacturer and the 3PL provider.

■ TA-05

Tuesday, 8:30-10:00 - TIC Auditorium C, Level 2

Resource Efficiency in Interorganisational Networks

Stream: OR for Energy and Resource Efficiency
Invited session
Chair: *Stefano Saetta*
Chair: *Nils Lerche*

1 - About the potential of MCDA-methods to foster stakeholders' participation in local energy projects

Nils Lerche, Ines Wilkens, Meike Schmehl, Swantje Dr. Eigner-Thiel, Jutta Geldermann

The creation of stakeholders' acceptance is of growing importance for the realization of projects in the energy sector. Multi-Criteria Decision Analysis allows not only to assess alternatives by taking various criteria into account, but also to let stakeholders participate in the decision process and consider their concerns (e.g. Miller, Belton 2014). In fact, participation can help to increase peoples' acceptance towards projects. A renewable energy source for the supply of heat, power or fuels is biomass. However, on a local scale, there often exist very different viewpoints regarding the realization of small-scale bioenergy projects, e.g. due to noise or increasing of monocultures. Hence, the application of MCDA-methods seems to be suitable to support local small-scale bioenergy projects, since they both are able to incorporate various criteria and offer stakeholders an opportunity to participate in the decision process. A case study concerning the identification of a sustainable bioenergy concept for a rural German village is presented. In this context, potential opportunities and challenges of an application of MCDA-methods are discussed. References: Miller, K.A.; Belton, V. (2014): Water resource management and climate change adaptation: a holistic and multiple criteria perspective, in: Mitigation and Adaptation Strategies for Global Change, 19 (3), pp. 289 - 308

2 - Optimization-aided Resource Efficiency Analysis of a Metallurgic Production Process for Refractory Metals

Hendrik Lambrecht, Heidi Hottenroth, Tobias Schröer, Frank Schulenburg

A prototypic optimization tool is presented that has been developed within an interdisciplinary research project dealing with integrated resource efficiency analysis in the chemical industry. It is based on a combination of material and energy flow analysis (MEFA) with mathematical programming (MP): Material flow models are automatically transformed to mathematical programs which are solved using standard methods of MP. In this context, MEFA is used as a graphic-based and thus particular intuitive approach to system optimization. It moreover provides a useful interface to life cycle assessment (LCA) methods and databases needed for including supply chain information on indirect environmental impacts. MP, in turn, enables the identification of resource efficient operating conditions or designs for the typically large and complex production facilities in the chemical industry.

A particularly interesting area of application arises from using the optimization tool during model formulation. Such an "optimization-aided' MEFA allows for the systematic exploration of the decision-makers action space and helps constructing valid optimization models. Optimization can thus disclose improvement potentials which go beyond standard solutions and are, for this very reason, particularly useful in practice. The optimization tool as well as these conceptual aspects are illustrated by applying it to a real production facility from the technology metals sector.

3 - Including regeneration possibilities to increase water reuse in scheduling multipurpose batch plants

Pulluru Sai Jishna, Renzo Akkerman

Water scarcity and pollution have posed a serious threat to various industries, necessitating them to reduce their water consumption. Process industries are one of the major users of water and often face the stringent water regulations imposed by governments. In this context, scheduling of multipurpose batch process plants has started integrating water reuse objectives in recent years. From a technological perspective, reuse options can be increased with the inclusion of water regeneration or treatment processes. The water is generally purified to an extent at which reuse of the effluent water is made possible in further processes. However, the purity of such water streams and time required for such purification is highly dependent on the type of regeneration process employed and significantly alters the flexibility of schedules which are already constrained on the use of water. Furthermore, the integration of regeneration possibilities in the already complex scheduling of multipurpose batch plants often leads to the consideration of multiple objectives as well as computational challenges. This study aims to examine the impact of including regeneration possibilities on the flexibility of scheduling procedures and focuses on gaining insight in the trade-offs between cost-optimal and water-efficient production schedules in a multipurpose batch plant setting.

4 - Operations Research tools for food supply chain at small scale

Stefano Saetta, Valentina Caldarelli

One of the most interesting fields of interest in the next future Is the distribution of food in small scale. This for several reasons: new technologies, new usances, high variety of food available, high standard of quality living, organic food, healthcare prevention etc. In this sense food distribution seems to be a field that will receive attention from operators in the next years. Operations research tools can offer a variety of solution that can be user to develop new models of food distributions. In the presentations some of those models will be discussed based on a real case.

■ TA-06

Tuesday, 8:30-10:00 - TIC Lecture Theatre, Level 1

POM Applications III

Stream: Production and Operations Management
Invited session
Chair: *Erdal Emel*

1 - Dynamic flexible job shop scheduling under stochastic demand

Erdal Emel, Ümit Eraydın Genç

In a flexible job shop, manufactured parts are pulled by succeeding assembly lines in a stochastic order. Inventory of manufactured parts before the assembly stage are proposed to be managed by a dynamic scheduling algorithm based on a combination of shortest processing times, inventory depletion rates and minimum inventory level criteria. The flow of material through manufacturing, inventory and assembly stages is facilitated and controlled both with Kanban cards and an electronic job shop ordering system running the scheduling algorithm.

The algorithm is first tested on a simulation environment comparing to other sequencing approaches such as FCFS, Total SPT, due date and shortest bottleneck process time. Proved to be superior to others, next, it is implemented in a real world environment running on top of an ERP system. Results of simulation verified by the real world implementation have demonstrated the applicability of the proposed scheduling algorithm to minimize inventory levels under stochastic customer demands.

2 - Control of M/Coxian-2/s Make-to-Stock Production Systems with Multiple Demand Classes
Ozgun Ozturk, Onder Bulut, Ozge Buyukdagli

This study considers a make-to stock production environment with multiple production channels, lost sales and several demand classes. Demands of customer classes are generated according to independent and stationary Poisson processes and the production times are assumed to be 2-phase Coxian. In this setting, at any system state, we aim to identify how many production channels should be activated and how to allocate a common stock pool among different customer classes. We model this system as an M/Coxian-2/s make-to-stock queue where s denotes the available number of production channels. The rationale behind the 2-phase Coxian processing times assumption is threefold: i. since the second production stage is visited with a certain probability, this stage can be seen as the rework operation after the main process and inspection, ii. M/Coxian-2/s model is a direct extension of M/M/s model, iii. when the production rates are equal at each stage and the probability that an item visits the second stage after the first one is set to be one, the model turns out to be the M/E_2/s model which enables us to study the multi-server systems with Erlangian processing times. First, we characterize the structure of the optimal production and rationing policies which are state dependent and not so easy to apply in practice. Secondly, we propose new production and rationing policies and asses their performance by comparing them with the optimal ones and with the ones suggested in the literature.

3 - Scheduling a micro-biological laboratory: combinatorial properties of zero-one matrices
Celia Glass

I will outline the various scheduling problems inherent for a food testing micro-biology laboratory, and then focus an unusual one of coordinating two key scheduling processes. Each food sample requires a whole suite of tests to be performed successfully in order to be certified fit for consumption. Each test within a test suite is carried out on a glass dish, in an agar compound specific to the nature of the test. Thus the sequence of samples determines parallel demand for a range of agars. A major limitation is the limited effective lifetime of the agars. We focus on coordinating the scheduling test samples with the production of agars. A sequence of agar combinations is represented as a (0,1)-matrix specifying agar combinations of test samples. The objective is to find a permutation of its rows for which the total number of zero-entries situated between the blocks of consecutive ones in the columns of the permuted matrix is minimized. The problem is related to the classic Consecutive Ones Problem, and is NP-hard. I present an optimization approach based on indirect enumeration of the solution space, and two heuristic algorithms: a greedy insertion algorithm and a more complicated implicit construction technique. Results are given for a wide range of randomly generated problem instances and also data from the micro-biological laboratory itself.

■ TA-07
Tuesday, 8:30-10:00 - TIC Conference Room 1, Level 3

Stochastic Models in Renewably Generated Electricity

Stream: Stochastic Models in Renewably Generated Electricity
Invited session
Chair: *John Boland*

1 - Scheduling of energy and reserve in renewable-dominated power systems
Miguel Carrión, Ruth Dominguez, Javier Rodríguez Villamayor

During the last years the electricity production by means of renewable energy has highly increased all around the world. In the near future it is expected that the electricity demand is provided by renewable-dominated power systems. Because of the intermittent nature of most renewable sources, an appropriate scheduling of reserves is crucial in fully-dominated renewable systems in order to ensure a reliable procurement of demand at minimum cost. In this work, two different strategies for energy and reserve scheduling are analyzed. Specifically, we compare the performance of a decoupled scheduling of energy and reserve with respect to a scheduling strategy that co-optimizes energy and reserve simultaneously. The uncertainty pertaining to the production of renewable resources is explicitly considered. The analyzed models are tested in a realistic case study based on the Iberian Peninsula Power System.

2 - Strategic behaviour and ownership of energy storage systems in pool-based electricity markets
Karl Hartwig

The business case for Energy Storage Systems (ESS) as an alternative to traditional network reinforcements can be improved if the ESS are able to access additional revenue streams by participating in energy and ancillary services markets. To enable this, the storage needs to be operated by private merchants to circumvent the unbundling principle applied in electricity markets today. However, it is not clear if the right incentives are in place to operate the ESS in a way that supports the wider system welfare. This work seeks to evaluate the strategic behavior of an independent trader operating ESS in a pool based electricity market. The interaction between the ESS operator and the Market Operator (MO) is modelled as a Stackelberg Game where the impact of ESS bids and offers on the price formation is modelled by a bi-level optimization problem. The upper level problem maximizes ESS profits by anticipating the actions of the MO whose market clearing is modelled in the lower level problem. The latter contains a DC-Optimal Power Flow formulation to evaluate the possibility to exploit network topology and congestion to increase ESS profits and hence enable a way to identify market conditions that are likely to lead to ESS gaming.

3 - Adaptive short term probabilistic forecasting of solar radiation
John Boland

We have previously used the CARDS short term forecasting tool for solar radiation to good advantage. We present improvements to this model in two ways, first adding adaptive parameter estimation, and second, adding prediction intervals to the forecast.

■ TA-09
Tuesday, 8:30-10:00 - TIC Conference Room 3, Level 3

Vendor Session I: AMPL and Elsevier

Stream: Vendor Sessions
Sponsored session
Chair: *Robert Fourer*
Chair: *Ruben Ruiz*

1 - Adding Optimization to Your Applications: Efficient and Effective Strategies Using Algebraic Modeling with AMPL
Robert Fourer

Algebraic modeling languages have been developed with the goal of making optimization models much easier to develop, debug, and maintain. Moreover it is not necessary to give up these advantages when embedding a model into a larger system or deploying it to users. This talk describes features of the AMPL modeling language that work together to help you build optimization models quickly and use completed models effectively. Following an introduction to development of algebraic optimization models, the presentation introduces two distinct modeling language facilities commonly used to integrate models into projects and applications. Scripting brings the programmer to the modeling language, extending the language so that the same constructs convenient for describing a model can also be used to specify how the model will be used in a broader context. APIs bring the modeling language to the programmer, providing access to model objects and methods for applications written in general-purpose programming languages. The strengths of these approaches are contrasted using a common example.

2 - Operations Research Perspectives, open access futures, and the art of writing good papers
Ruben Ruiz

Find out what sets Operations Research Perspectives apart. This new journal, published by Elsevier, has three distinct traits: it is fully open access, it has a broad scope (the journal invites papers from all subfields of operations research), and it has an accelerated revision process. Come to the vendor stream to find out more about the journal and what open access means for authors and the future of operations research. You'll also find out how you can write stronger papers to increase your chances of getting published in high impact journals. You'll gain invaluable insights into the editorial process and be given top tips on how to write excellent and high-impact papers. Want one on one feedback on your research? Come to the Elsevier booth to book your spot in our Editor Feedback Sessions.

■ TA-12

Tuesday, 8:30-10:00 - TIC Conference Room 4&5, Level 3

Operational Challenges of Electrified Mobility

Stream: Long Term Planning in Energy, Environment and Climate
Invited session
Chair: *Edi Assoumou*

1 - Strategies for Charging Electric Vehicles in the Electricity Market
Giovanni Pantuso, Nina Juul, Trine Krogh Boomsma, Emil Banning Iversen

Different charging strategies for a fleet of electric vehicles are analyzed. Along with increasing the realism of the strategies, the opportunity for acting on the regulating market (i.e., intra-day electricity markets activated after the day-ahead market is cleared) is also included. Particularly, strategies are chosen from uncontrolled charging through deterministic optimization, to modelling the charging and bidding problem with stochastic programming. Based on instances generated with historical market data from Denmark, we show that vehicle owners will benefit from using more sophisticated strategies such as using stochastic optimization. Furthermore, the high value of the stochastic solution shows that, in case the regulating price differs from the expected, the solution to the deterministic problem becomes infeasible in practice.

2 - Optimal mileage of electric vehicles considering range anxiety and charging times
Xiuhong He, Wenjie Zhan

This paper aims to find out the optimal mileage of electric vehicles (EVs) considering the trade-off between range anxiety and charging times, since the fact that frequent charging is a customary way to ease range anxiety for drivers in practice but declines the life circle of battery and increases the charging cost. Two types of optimal mileages are examined, the absolute mileage and the relative mileage. The former is defined as the driving mileage before each full charge, and the latter is the ratio of absolute mileage to EVs' cruising range. Firstly, we propose an exponential function to measure the range anxiety, which is related to the relative mileage and the driver's tolerance to range anxiety. Then, the two optimal mileages are solved. The results show that the increment of EVs' cruising range increases the optimal absolute mileage but decreases the optimal relative mileage, while the improvement of driver's tolerance to range anxiety increases both. It is concluded that improving driver's tolerance, such as expanding charging infrastructures and raising driver's practical experience with EVs, is more effective.

3 - The role of Electric vehicles in Europe by 2030 and 2050
Markus Blesl

What will be the perspective of electromobility in the EU28 as a whole and in the member countries is one main question at the moment. By considering different scenarios with varied assumptions concerning energy, climate and environmental policy in the EU the role of electromobility will be analysed. The analysis will be done by using a multi-regional energy system model of the EU28 plus Switzerland and Norway (TIMES PanEU). By considering a perfect competition among different technologies and pathways of energy conversion the model minimizes the total discounted system costs over the time horizon from 2010 to 2050. In the context of electric mobility different powertrain concepts are distinguished in the model. In order to comprehensively assess the future role of electric vehicles, the possibility of vehicle-to-grid energy storage is taking into account. The results of the scenario shows that an economic expansion of hybrid electric vehicles used at the earliest in 2030 and in subsequent years to 2050 leads to significant market shares in the stock of vehicles in passenger cars and light commercial vehicles. Only under a scenario with an extreme climate protection target and estimated big efforts in the direction economies of scale in battery technology, these electric cars reach on EU level a market share of 70% for cars and 4% for commercial vehicles and buses.

4 - Load curve impact of large electric vehicles fleet in the Paris Île-de-France region
Edi Assoumou, Jean-Paul Marmorat

Electric vehicles are expected to play an important role in a more sustainable future for the transport sector. The Ile-de-France region centered on Paris has thus set the ambitious objective of 1 million electrified vehicles by 2030. The objective of this study is hence to investigate the technical and economic interaction between mobility needs and the electricity network for the Paris-Ile-de-France region. The central element discussed is the load curve impact of a large fleet of vehicle. The problem can be described as the need to satisfy non coordinated trip demands for a typical week day that stem from the mobility demand of individual car owners. It is constrained by contextual elements such as batteries capacity limits, energy requirement to satisfy the mobility demand, charging infrastructure and preferences in charging behavior. We address that issue at a sub-hourly time step and using a total charging cost minimization paradigm. Over 50 charging contexts are analyzed to quantify the impact of electrified mobility on the current load curve in the Ile de France region and identify the main assumptions that affect this profile.

■ TA-15

Tuesday, 8:30-10:00 - TIC Conference Room 6&7, Level 3

Cutting and Packing 5

Stream: Cutting and Packing
Invited session
Chair: *Kelly Cristina Poldi*

1 - On-line Integrated Cutting and Packing Plan Optimization in a Steel Bar Mill
Pablo Valledor Pellicer, Diego Diaz Fidalgo, Silvino Fernández Alzueta, Alejandro Fernández Alonso

An important performance driver in industrial production processes is the reduction of material losses; in the steel industry this is the scrapped material. In the scope of bar mills, the main factor impacting these losses is the cutting process. An optimization of the cutting plan schedule, based on material losses minimization is not sufficient, as a trade-off between losses and productivity is required in order to balance cost and productivity. This requires the inclusion of both the cutting and packing processes, since packing is the main bottleneck in productivity.

In this work, we introduce the problem of scrap minimization in a specific bar mill capable of cutting several bars at once, in a layer, and balancing the production towards 2 piling machines for packing. We show this problem to be a substantial extension of the 1D cutting stock problem, with additional constraints due to the ordering of the layers, relationships between orders spanning more than one layer, and piling machines load balance consideration. Additionally the use of the model in real time by the cold saw operators imposes a reduced budget of computing time.

We develop an Ant Colony Optimization algorithm with a strategy based on efficient cutting patterns for search space reduction and a heuristic to deal with the complexity of finding good feasible solutions. We evaluate its performance on actual mill data covering different characteristics to show the usefulness of the algorithm.

2 - Algorithms for the Multi-Stage Cutting Stock Problem
Ibrahim Muter

In the one-dimensional multi-stage cutting stock problem, operational restrictions impose that stock rolls are cut into nished rolls in more than one stage. In the rst stage, a stock roll is cut into intermediate rolls, while nished rolls are produced from these intermediate rolls in the second stage. The objective is to minimize the number of stock rolls used for satisfying the demand for nished rolls, and appropriate cutting patterns need to be identied for each stage in the cutting process. The difficulty of this problem stems from the fact that the set of intermediate rolls is unknown. For the mathematical model of this problem, we explain the application of simultaneous column-and-row generation which results in a subproblem with many columns. This subproblem is called a row-generating subproblem which introduces new rows corresponding to the intermediate rolls to the model along with the patterns. We propose two strategies to solve the pricing subproblem which is basically a knapsack problem. One of these strategies is based on column generation within a known algorithm for the knapsack problem. The other one generates the intermediate roll set a priori by using dominance relations. Finally, we conduct computational experiments on the performance of these approaches. This study is supported by The Scientific and Technological Research Council of Turkey (TUBITAK) under grant 113M480.

3 - A Mathematical Model Based Heuristic Method for Two-Dimensional Cutting and Assortment Problem
Banu İçmen, *Refail Kasimbeyli*

In this study we consider two-dimensional cutting stock and assortment problems under various assumptions and guillotine cutting constraints. In order to solve two-dimensional cutting stock and assortment problem, a mathematical model based heuristic method is proposed. The proposed method solves the two-dimensional cutting stock problem in two phases. In first phase, we determine the demand list for each stock then in second phase we place each item. We use this approach to solve some test problems from literature.

4 - Mathematical Modeling for the Multiperiod Cutting Stock Problem
Kelly Cristina Poldi, *Silvio de Araujo*

The multiperiod cutting stock problem arises in the production planning and programming in some industries. The demanded items are required in different periods of a finite planning horizon. In several cases, it is possible to anticipate or not the production of items and, such anticipation could lead to a better combination of items, generating lesser waste. Unused inventory in a certain period becomes available to the next period, all together with new inventory which may be acquired. Based on mixed integer optimization models from the literature, two generalizations are proposed to deal with the multiperiod case. Computational experiments showed that effective gains can be obtained when compared multiperiod models with the lot for lot solution, which is typically used in practice.

■ TA-16
Tuesday, 8:30-10:00 - TIC Conference Room 8, Level 3

Stochastic and Dynamic Lot Sizing

Stream: Lot Sizing, Lot Scheduling and Related Problems
Invited session
Chair: *Roberto Rossi*
Chair: *Armagan Tarim*
Chair: *Steven Prestwich*

1 - A Comparison of Lot-Sizing Methods for Non-Stationary Stochastic Demand
Gozdem Dural-Selcuk, *Onur A. Kilic*, *Armagan Tarim*, *Roberto Rossi*

In this paper, we consider the single-item single-stocking location stochastic lot-sizing problem under non-stationary demand. We investigate the cost performance of a variety of methods proposed for this problem. We take into consideration both conventional and rolling horizon implementations. We conducted an extensive numerical study

to analyze the eect of a large spectrum of demand and cost parameters on the cost performance of dierent approaches. The contribution of this study is two-fold. First, we provide a cost-based comparison of dierent methods, and we show how dierent methods perform under dierent parameter settings. Second, we present numerical evidence on the eectiveness of control strategies with static and/or dynamic proposals on inventory control decisions regarding the timing and the size of replenishment.

2 - A multi-period production-inventory planning model for multi-products with fixed shelf life
M. Karimi-Nasab

The paper examines a production and inventory planning problem for products that have fixed shelf lives. It is assumed that each product type has a predetermined fixed shelf life after which it is considered unsuitable for use. A first-in-first-out (FIFO) inventory picking policy is used to select items from the warehouse. Shortages are allowed in the form of partial backordering. Also, it presents a new mathematical formulation that determines optimal production and inventory plans for multiple deteriorating products, where the problem formulation is an integer linear program. The model is developed so that it does not need to consider integrality conditions of variables except for specific binary variables of setups. Hence, a branch and bound algorithm can be used to provide an efficient method for solving the model. A numerical example is solved to demonstrate the model properties. The example examines over 12 periods, two productsproduced by an industrial company in Iran. Given the demand data, the model produces the periodic production volumes, the inventory levels and the optimal total cost for a range of shelf life values. The sensitivity of the costs to different shelf lives is illustrated and the implications of using the approach for practical production planning are discussed.

3 - A Computational Study for the Inventory Routing Problem
Yasemin Malli, *Marco Laumanns*, *Steven Prestwich*, *Roberto Rossi*, *Armagan Tarim*

In this paper, we have a set of retailers each of which face a deterministic demand for a given product. The retailer can order this product from a warehouse. The warehouse dispatches an unlimited truck to deliver product to the retailers. The truck leaves from the warehouse, visits all the retailers which are replenished once and then return back to the warehouse by using the route that has minimum distance. There are transportation costs associated with the route followed by the truck to reach a given retailer. Inventory cost includes holding cost and fixed ordering cost. It is assumed that the capacity of warehouse and retailers are unlimited. The distance between retailers is known. The objective is to determine the optimal replenishment plan and vehicle routes for each retailer. We consider the routing part of the problem as a traveling salesman problem (TSP). We survey several mixed integer linear programming formulations of TSP in literature. For the inventory part of the problem, we overview classical mixed integer linear programming formulation based on dynamic programming formulation and shortest path formulation for inventory control models. We present a computational study which combines the existing TSP formulations and inventory control models. We contribute to literature by evaluating the cost performance and solution time of combining the existing optimal and near optimal TSP formulations and inventory control policies.

4 - Neural Policies for Stochastic Dynamic Lot Sizing
Carlo Manna, *Roberto Rossi*, *Armagan Tarim*, *Steven Prestwich*

In this paper we address the single product and single stocking point stochastic inventory control problem with non-stationary demand. The planning horizon is finite and composed of discrete time periods. This well-known control problem takes into account the costs of placing an order, which is a fixed cost, and linear inventory holding and shortage costs. In his seminal paper, Scarf proved that the optimal control policy for this problem is of (s,S)-type, where s is the reorder-point, and S is the order-up-to-level. Since demand is non-stationary and planning horizon is finite the optimal control parameters are dynamic (i.e, in the form of (st,St). The conventional approach to tackle this problem is Stochastic Dynamic Programming. However, when side-constraints, like constraints on order quantities, are introduced most of the time the form of the optimal policy is not simple anymore and the application in practice is very limited. In this work, we adopt a neural policy to solve this well-known problem and its variants. These problems are tackled without exploiting any background information related to the structural properties of the optimal policy or the solution. We show that the neural approach proposed in this paper is very effective in tackling the original problem as well as its variants. Our numerical experiments

demonstrate that the proposed method yields near-optimal solutions in reasonable times.

■ TA-17

Tuesday, 8:30-10:00 - TIC Conference Room A, Level 9

Logistics and Transportation in Biomass-based Supply Chains

Stream: Biomass-Based Supply Chains
Invited session
Chair: *Magnus Fröhling*

1 - A general mixed integer linear model for a local biorefinery supply chain
Birome Holo Ba, Christian Prins, Caroline Prodhon

The last decades have seen a growing interest in the potential of bio-fuels as a means of reducing dependence on fossil fuels and in the development of clean and renewable energy. This domain raises interesting logistic optimization problems, to supply the conversion units regularly, reliably, and with sufficient quantities of quality biomass at reasonable prices. In fact, the economic viability critically depends on logistic costs, which represent a significant part of biomass cost at the gate of a refinery. We address a multi-product, multi-period supply problem raised by a proximity refinery. We propose a mixed integer linear programming (MILP) model dealing with different feedstock production operations, such as harvesting, storage, and transportation, with the objective of minimizing the total logistics costs of the system on a regional basis. It determines the number of farm equipment, the fleet size of trucks for transportation and the amount of each type of biomass harvested, stored and transported in each period to satisfy demands of bio-refineries given per period. The modeling approach is general enough to be extended to most supply chains for bioenergy, at the tactical level. The effectiveness of the proposed model is illustrated with a numerical example, which gives preliminary but interesting results. As commercial MILP solvers need too much CPU time to reach an exact solution on large instances, the development of heuristics is an interesting perspective.

2 - Dealing with a Divergent Production Structure at a Sawmill — Comparing Different Solution Approaches
Maria Anna Huka, Manfred Gronalt

One of the mayor aspects and problems of dealing with the production planning at a sawmill is the divergent production structure from heterogeneous raw material to products. When making a product with one cutting pattern, several other main products and by-products are produced simultaneously. How to deal with this "unwanted" production is the key aspect of this work. We investigate different planning approaches such as one-period planning, short term multi-period planning and a planning horizon. The decision making models are formulated as mixed-integer programs where we consider maximizing the contribution margin but also minimizing the costs. Not only the net revenue but also the variable costs of the production, inventory costs for raw material and products. The purchasing price for raw material, the backlog costs for products and the stock value at the end of the planning horizon are taking into account. These optimization approaches will be compared to simple heuristic which are used currently at sawmills or could easily be implemented there to see the gap between the solutions.

3 - A Stochastic Model for Harvesting and Supply in Forestry Problems under Uncertainty
Adejuyigbe Fajemisin, Laura Climent, Steven Prestwich, Barry Osullivan

We present a traditional timber supply problem from multiple forests with multi-cutting instructions in which demand must be satisfied, while minimising the harvesting and transportation costs. We extend this problem to include uncertainty in the log product yields, which are imprecise as a result of the uncertainty in the forest capacity. Several factors contribute to the uncertainty in the capacity of a forest. In our case, the total capacity of the forests was estimated by sampling small sections of the forests, thus introducing sampling and measurement errors.

From an industrial point of view, it is very important to find solutions that consider such uncertainties and ensure suppliers put adequate plans in place in order to fully satisfy their customers. We therefore developed a scenario-based stochastic model to incorporate the uncertainty in the problem. We also added a service-level constraint in order to ensure that in at least 95% of the scenarios, the demands of the customers were satisfied, and the model was evaluated on data obtained from industry.

■ TA-18

Tuesday, 8:30-10:00 - TIC Conference Room B, Level 9

Energy Market Modeling 2: Equilibrium Models

Stream: Energy Market/System Modeling
Invited session
Chair: *Daniel Huppmann*
Chair: *Emre Çelebi*

1 - Sequential coordination of transmission expansion planning with strategic generation investment
Yaser Tohidi, Mohammad Reza Hesamzadeh

This research proposes a framework for solving the multi-level structure of transmission and generation investment in deregulated power systems for two different types of proactive and reactive coordinations. In proactive coordination, transmission planner decides first in the upper-level and generation planners decides next in the lower-level. In reactive coordination, this sequence is vice versa. The transmission planner is assumed as a social welfare maximizing entity and the behavior of generators is modeled as the Nash equilibrium of a strategic game. The framework proposed uses a methodology based on the Moore and Bard branch and bound algorithm. The developed models and the proposed framework are implemented on an illustrative example and then on IEEE-RTS96 and IEEE 118-bus test systems and the results for two types of proactive and reactive coordinations are compared.

2 - Aggregation of Price-Responsive Units Using Inverse Optimization
Javier Saez-Gallego, Juan Miguel Morales, Marco Zugno, Henrik Madsen

We consider the market bidding problem of an aggregator of price-responsive consumers. These consumers are, therefore, able to react to the electricity price, e.g., by shifting their consumption from high-price hours to lower-price hours. The total amount of electricity consumed by the aggregation has to be purchased in the electricity market. Therefore, the aggregator has to place a bid into such market that represents the response of the pooled consumers. Traditionally, this bid would be a forecast of the load, since the load has commonly behaved inelastically. However, in this paper, we consider a market that accepts a more complex bid that better represents the reaction of the load. This bid consists of a stepwise utility function, maximum pick-up and drop-off rates and maximum and minimum power consumption, in an analogous manner to the offers from power producers. We propose a original approach to estimate the parameters of the bid based on inverse optimization and bi-level programming. Furthermore, we use a large dataset of external information to partly explain the parameters of the bid. Finally, for the case study, we use data relative to the Olympic Peninsula project to asses the performance of the proposed model. Results show that the estimated bid is capable of representing the complex behavior of the pool in a way that can be used for the pool of consumers to participate in the market.

3 - Comparison of Four Models of Near Equilibrium for a Centrally Dispatched Pool Market with Nonconvexities
Emre Çelebi, David Fuller

In many electricity markets, the market operator solves a social welfare maximization model to determine market prices and generation (and consumption) instructions to generators (large consumers) who participate in the market by submitting information about their costs (benefits) to the operator. When the cost (benefit) functions are described as mixed integer programs, linear prices cannot, in general, be found such that all market participants are satisfied that the generation (consumption) instructions from the operator maximize profits (net benefits). We

define a measure of such disequilibrium and a model that minimizes total disequilibrium in the market, and we compare it to three other models which have been proposed —social welfare maximization, social welfare maximization with constraints that ensure non-negative profits for market participants, and a minimum complementarity model recently proposed by Gabriel, Conejo, Ruiz and Siddiqui (2013). We prove several theoretical results, including one which gives an economic interpretation for the minimum complementarity model for the first time. We illustrate the models by applying them to two specific examples of unit commitment decisions —a simple, single-period case without a transmission network, and a multi-period case with a network.

4 - Exact solutions to binary equilibrium problems with compensation and the power market uplift problem
Daniel Huppmann, Sauleh Siddiqui

We propose a novel method to find Nash equilibria in games with binary decision variables by including compensation payments and incentive-compatibility constraints from non-cooperative game theory directly into an optimization framework in lieu of using first order conditions of a linearization, or relaxation of integrality conditions. The reformulation offers a new approach to obtain and interpret dual variables to binary constraints using the benefit or loss from deviation rather than marginal relaxations. The method endogenizes the trade-off between overall (societal) efficiency and compensation payments necessary to align incentives of individual players. We provide existence results and conditions under which this problem can be solved as a mixed-binary linear program.

We apply the solution approach to a stylized nodal power-market equilibrium problem with binary on-off decisions. This illustrative example shows that our approach yields an exact solution to the binary Nash game with compensation. We compare different implementations of actual market rules within our model, in particular constraints ensuring non-negative profits (no-loss rule) and restrictions on the compensation payments to non-dispatched generators. We discuss the resulting equilibria in terms of overall welfare, efficiency, and allocational equity.

■ TA-25
Tuesday, 8:30-10:00 - John Anderson JA3.14 Lecture Theatre

Linear Vector Optimization

Stream: Continuous Multiobjective Optimization and Robustness
Invited session
Chair: *Andreas Löhne*

1 - Applied Vector Optimization: Hunt for New Entropy Inequalities
Laszlo Csirmaz

The structure of the entropy region is mostly unknown, even partial knowledge about this region has far reaching consequences in other areas in mathematics, like information theory, cryptography, probability theory and combinatorics. All known methods to explore this region require solving a high dimensional, highly degenerate vector optimization problem. After a gentle introduction to the fascianting area of entropy inequalities and sketching the vector optimization problem whose solutions might lead to the new inequalities, we present a new optimization paradigm arising from this application: the feasible region is not given explicitly, rather by a separation oracle, which, on each question, returns an optimal solution for a scalar optimization problem. Benson's algorithm has been adapted to cover optimization using either facet or vertex separation oracle. The algorithm has been applied successfully to get numeruous new entropy inequalities, in many cases the underlying vector optimization problem had twelve objectives, over 500 dimensional problem space, and over 5000 linear constrains.

2 - Algorithms for Solving the Problem of Locating a Semi-obnoxious Facility - An Application of the Geometric Duality Theory for Linear Vector Optimization Problems
Andrea Wagner

This work deals with the non-convex optimization problem of locating a new facility which is necessary for certain aspects of social life but may also adversely affect the quality of life of people or animals in the surrounding area.

Although, a scalar optimization problem is considered, this work shows interesting relations to the fields of linear vector optimization and geometric duality theory.

Based on those relations and the duality theory by Toland and Singer we formulate a dual pair of algorithms, which determine exact solutions by relating the non-convex optimization problem to a finite number of linear problems.

3 - Primal and Dual Multi-objective Linear Programming Algorithms for Linear Multiplicative Programmes
Lizhen Shao, Matthias Ehrgott

Multiplicative programming problems (MPPs) are global optimisation problems known to be NP-hard. In this paper, we employ algorithms developed to compute the entire set of nondominated points of multi-objective linear programming (MOLP) problems to solve linear MPPs. First, we improve our own objective space cut and bound algorithm for convex MPPs in the special case of linear MPPs by only solving one linear programme in each iteration instead of two as the previous version indicates. We call this algorithm, which is based on Benson's outer approximation algorithm for MOLP problems, the primal objective space algorithm. Then, based on the dual variant of Benson's algorithm, we propose a dual objective space algorithm for solving linear MPPs. The dual algorithm also requires solving only one linear programme in each iteration. We prove the correctness of the dual algorithm and use computational experiments comparing our MOLP based algorithms to a recent global optimisation algorithm for linear MPPs from the literature as well as two general global solvers to demonstrate the superiority of the new algorithms in terms of computation time. Thus we demonstrate that the use of multi-objective optimisation techniques can be beneficial to solve difficult single objective global optimisation problems.

4 - Convexification in Global Optimization Using Vector Linear Programming
Andreas Löhne

Certain classes of non-convex scalar optimization problems, among them the linear bilevel problem and the semi-polyhedral DC optimization problem, can be decomposed into finitely many convex programs. We discuss capabilities and limitations of this approach to finding exact solutions for global optimization problems.

■ TA-26
Tuesday, 8:30-10:00 - John Anderson JA3.17 Lecture Theatre

Call Centers

Stream: Stochastic Modeling
Invited session
Chair: *Benjamin Legros*

1 - When to initiate and when to reject a call in a multi-channel blended call center.
Benjamin Legros, Oualid Jouini, Ger Koole

We study strategies of rejection in multi-channel blended call centers with inbound and outbound calls. The following questions are addressed: How should the rejection of inbound calls from the queue be done and when should the agents initiate outbound calls in a way that will answer the performance objectives of the firm? In a multi-channel call center, the firm is looking for the best possible trade-off between the outbound calls throughput, the waiting time in the queue of inbound calls and the proportion of rejected callers. We tackle these questions by characterizing scheduling policies that are optimal. Using a Markov Decision Process approach we prove that the optimal policy is of switch type for the reservation of agents for inbound calls and for the rejection of inbound calls from the queue. Two classes of policies for rejection are considered: Rejection at arrivals, so-called rejection a priori and rejection after experimenting some wait, so-called rejection a posteriori. The derivation of the performance measures with their monotonicity properties in their control parameters allows us to find the optimal control parameters for reservation and rejection. The

two classes of policies for rejection are therefore compared. Our main finding is that although a rejection a posteriori seems unfriendly to customers who experienced some wait without being served, it provides a better performance for served customers.

2 - Performance approximation of time-dependent queueing systems with abandonments.
Gregor Selinka, Raik Stolletz

In many service systems, customers leave the queue if their waiting time exceeds their personal patience. Furthermore, queueing systems are often characterized by non-stationary behavior. Hence, the arrival process may be time-dependent, e.g., when considering arriving calls in an inbound call center.

This work deals with the performance of such single-stage queueing systems under non-stationary conditions that include abandonments. First, we present a literature review of time-dependent approaches for their performance evaluation. Second, two new versions of the stationary backlog-carryover (SBC) approximation and the modified offered load (MOL) approximation are developed and compared numerically.

3 - The effect of random waits on customer queue joining and reneging behavior: a laboratory experiment
Zeynep Aksin, Busra Gencer, Evrim Didem Gunes, Ozge Pala

In many service settings, customers encounter queues and have to decide between joining, balking and reneging. This study investigates customers' queue joining and reneging behaviors by using laboratory experiments in which participants experience several observable queues with different characteristics in terms of queue length (long/short) and service times (deterministic/random fast first/random slow first) and decide to join, balk or renege. We analyze the effects of queue length and random service times on joining and reneging behavior.

4 - Optimal call center staffing
Ger Koole

We formulate the staffing problem in call centers as a newsvendor type problem, where the costs are the initial staffing costs plus the traffic management costs. This leads to a new way of call center staffing based on quantiles of the distributional forecasts, and to the optimality of WAPE.

■ TA-27
Tuesday, 8:30-10:00 - John Anderson JA3.27, Level 3

Scheduling in Logistics

Stream: Scheduling, Sequencing, and Applications
Invited session
Chair: *Frits Spieksma*

1 - Scheduling aircraft take-offs and landings on parallel runways
Alexander Lieder, Raik Stolletz

We present a dynamic programming approach for the aircraft scheduling problem that occurs at large, highly utilized airports: A set of aircraft is planned to leave the airport while another set is approaching the airport and preparing to land. The scheduling problem at hand is to assign a runway and an operation time to all take-offs and landings while meeting the sequence-dependent separation requirements between all pairs of operations on the same runway. The objective is to minimize the total costs incurred by delayed operations. The presented algorithm takes into account constraints incurred by the airport's runway configuration: Some runways may be used only for take-offs or only for landings, or can only be used by certain types of aircraft. Furthermore, schedules for closely-spaced parallel runways have to consider additional separation constraints, as operations on one runway also restrict the operations on the other. Due to the high combinatorial complexity of this problem, solution approaches presented in the recent literature are mostly heuristic, approximate, or restricted to solving very small problem instances, while the approach presented in this paper can solve comparatively large problem instances to optimality within short computation times.

2 - Airplane Boarding
Simone Neumann, Florian Jaehn

The time required to board an airplane directly influences an airplane's turn-around time, i.e., the time that the airplane requires at the gate between two flights. Thus, the turn-around time can be reduced by using efficient boarding methods and such actions may also result in cost savings. In the presentation, a general problem description as well as a classification scheme of different boarding methods is provided. Furthermore, a broad overview on the current literature in this field is given and further approaches are presented.

3 - Mixed integer programming for emission and flow time reduction for locks in sequence
Ward Passchyn, Dirk Briskorn, Frits Spieksma

On many inland waterways, locks are needed to maintain a suitable water level for navigation. Such locks constitute natural bottlenecks for the ships which travel along these waterways. We describe a stylistic setting representing a system of such locks arranged in a sequence, and consider the scheduling of this system. Clearly, when multiple locks are present, the operational decisions for one of the locks influence the arrivals of ships at other locks. Since ships may travel the waterway in the upstream as well as the downstream direction, the operating schedules for all locks are related. We introduce different mixed-integer programming approaches to model this setting and optimize the operating schedule for such a sequence of locks, as opposed to optimizing each of the locks individually. In particular, we show how including the speed of ships as a variable allows to minimize the pollutant emissions. In addition, we also consider the minimization of flow time and investigate the trade-off between the emission and flow time objectives. We perform some computational tests with instances based on realistic data in order to quantify this trade-off, and to investigate the performance gain that can be achieved over heuristic procedures that better reflect the current decision-making from practice.

4 - No-wait scheduling for locks
Frits Spieksma, Ward Passchyn, Dirk Briskorn

We consider an operational planning problem in waterway transportation. Consider a single lock that consists of m parallel chambers. The chambers operate independently of each other and are each characterized by two numbers: their lockage time and their capacity. The term lockage time refers to the time needed to bring a ship from the downstream water level to the upstream water level, or vice versa. The capacity gives an upper bound on the number of ships that may simultaneously be present within a chamber. Ships arrive at the locks at given times. A ship can arrive either from the upstream side, or from the downstream side (this is called the position of a ship). Our interest is on the existence of so-called no-wait schedules; these are schedules in which no ship has to wait. A relevant special case is the setting with two distinct chambers, and all ships having the same position (the uni-directional case). We show how this problem is related to interval scheduling, we give necessary and sufficient conditions determining the existence of a no-wait schedule in the special case described above, and we show how to find such a schedule in linear time. We prove that the uni-directional case of the problem is NP-complete in case the number of chambers is part of the input.

■ TA-28
Tuesday, 8:30-10:00 - John Anderson JA3.26, Level 3

Course timetabling, referee timetabling

Stream: Timetabling
Invited session
Chair: *Sanja Petrovic*

1 - Automated Timetabling - A case study with hybrid algorithms and GPU parallelization
Dionisio Agourakis, Nei Yoshihiro Soma

The scientific community has been studying timetable generation problems extensively since modern computers became available to educational institutions. It is important to acknowledge that its relevance lies both within academia, as it is a very challenging NP-Hard problem, and practice, as resource scheduling determines the majority of the operational budget and performance across the academic period.

This work aims at two major contributions to the timetabling and operations research communities: by providing a full working real-world example of automated course timetabling by the use of hybrid metaheuristics, deployed in a Brazilian high school and by providing a full GPU-parallelized simulated annealing solution to the faculty assignment problem on very large instances of a Brazilian university. We present modelling and computational challenges faced and the paths taken to solve them, as well as detailed performance analysis.

2 - A column generation approach for proving strong bounds to the high school timetabling problem

Luciana Buriol, Olinto Araújo, Arton Dorneles

School timetabling is a classic optimization problem that has been extensively studied due to its practical and theoretical importance. It consists in scheduling a set of class-teacher meetings in a prefixed period of time, satisfying requirements of different types. Due to the combinatorial nature of this problem, solving medium and large instances of timetabling to optimality is a challenging task. When resources are tight, it is often difficult to find even a feasible solution. Several techniques have been developed in the scientific literature to tackle the high school timetabling problem. Since the use of exact methods, as mathematical programming techniques, are considered impracticable to solve large real world instances, metaheuristics and hybrid metaheuristics are the most used solution approaches. In this paper we propose a multicommodity flow model for the high school timetabling problem. In addition, we apply Dantzig-Wolfe decomposition to the multicommodity flow model, propose a column generation algorithm, and present experimental results for well known instances of the problem. The results show that the lower bound obtained through our approach is tight and can be generated faster than previous approaches reported in the literature. Although we pay special attention to problems arising in Brazilian institutions, the proposed methods can also be applied in problem variants from different countries without losing generality.

3 - A two-stage model for optimizing the student flow of a university course timetabling problem

Hendrik Vermuyten, Jeroen Belien, Inês Marques, Stef Lemmens

Manual timetabling can be a difficult and time-consuming task. The planning department of the KU Leuven Campus Brussels is confronted annually with creating a university course timetable. Over the past years, the number of students at the campus has significantly increased, resulting in congestion at the escalators and corridors at the start and end of the lectures. Timetables also control the student flows: two consecutive lectures in classrooms that are close to each other cause less congestion than two consecutive lectures in classrooms that are far from each other. This paper formulates a two-stage mixed integer programming model for a university course timetabling problem. The objective is to build a feasible timetable which minimizes the student flow between classrooms. The first stage minimizes the violation of the teacher preferences by assigning lectures to timeslots and rooms. Labour legislation regarding the working hours of teachers is also taken into account. The second stage reassigns classrooms to lectures of the timetable of the first stage to minimize the student flow. The conceptual model is applied to the dataset of the Faculty of Economics & Management of the KU Leuven Campus Brussels and the results are compared with the formerly used manual timetabling procedure. In addition, the two-stage model is tested and validated with 21 adapted instances from the literature.

4 - Referee Scheduling in Soccer

Lindsey Eng, Nadia Chilmonik

In many small nonprofit organizations, manually scheduling volunteers is an unreliable and inefficient process. Due to budget constraints on these organizations, scheduling software is often too costly to be purchased. Additionally, learning curve for some software is too steep for it to be useful. There are many software products available on the market that improve manual scheduling practices, but none offer automated scheduling methods at a low cost. The objective of this research project is to create an automated scheduling and assignment algorithm for creating referee schedules for the DC Stoddert Soccer League. Beyond this goal, this research should create an adaptable model that can be used for a number of other scheduling purposes such as scheduling volunteers in a soup kitchen, work site volunteers, or interviewers. Using Microsoft Excel, this research will apply integer programming methods to find a cost effective, user friendly solution to this common problem. The model will use the standard Excel Solver, constraints will be generated based on survey data gathered from referees and the scheduling manager, and the output will assign backup volunteers to

each game, should the assigned referee cancel. The model we present in this paper is an example of how operations research methods can be used to create cost effective solutions for small nonprofit organizations.

■ TA-29

Tuesday, 8:30-10:00 - John Anderson JA4.12, Level 4

Early Warning Systems in Finance and Economy

Stream: Data Mining in Early Warning Systems
Invited session
Chair: *Ceyda Yazici*

1 - Stochastic Portfolio Optimization Using Efficiency Evaluation

Paulo Rotela Junior, Edson Pamplona, Luiz Celio Souza Rocha, Victor E M Valerio, Anderson P Paiva, Giancarlo Aquila, Marcelo Nunes Fonseca

The objective of this article is to the analyze portfolios chosen using efficiency evaluation with risk and uncertainty and optimize allocation of capital invested using the Sharpe approach. The portfolios were made up of shares on the Sao Paulo Stock Exchange. A Chance Constrained Data Envelopment Analysis stochastic optimization model was used for this purpose. The model was shown to be viable, reduced the search space and considered randomness of data. Three portfolios were proposed. The variation of the risk criterion of the model fulfilled the requirements of investors with different attitudes toward risk. The model proposed can be used as a support tool for stock investment decisions.

2 - Data Envelopment Analysis and Fuzzy Theory: Efficiency Evaluation under Uncertainty in Portfolio Optimization

Fernando Salomon, Paulo Rotela Junior, Edson Pamplona, Luiz Celio Souza Rocha, Victor E M Valerio, Giancarlo Aquila, Marcelo Nunes Fonseca

This article aims to analyze the behavior of a portfolio selected through Data Envelopment Analysis (DEA) associated with fuzzy logic and optimized using the Sharpe Index approach. As a basis for comparison, two other portfolios were used, one obtained through only the Sharpe Index approach. In this research study, a fuzzy DEA model was used to evaluate efficiency under uncertainty of the Brazilian Stock Exchange - Bovespa, by means of input and output indicators such as return, variance, earnings per share and price-earnings. The study reliably identified which efficient stocks and which were most sensitive to the effect of uncertainty. Through the comparison of portfolios, it was observed that the resulting combination of the fuzzy DEA models in which the stocks were considered efficient in both scenarios presented the best results.

3 - Investment Timing, Collateral, and Financial Constraints

Takashi Shibata, Michi Nishihara

This paper examines the optimal investment timing decision problem of a firm constrained to a debt issuance limit determined by collateral value. We show that the investment thresholds have a U-shaped relation with the debt issuance limit constraints, in that they are increasing (decreasing) with the constraint for high (low) debt issuance limit. Debt issuance limit constraints lead to debt holders experiencing low risk and low returns. That is, the more severe the debt issuance limits, the lower the credit spreads and default probabilities.

4 - Media Supervision and Shareholder Expropriation a Theoretical Framework Based on Stochastic Dynamic Optimization Model

Yongji Zhang

In this paper, we developed an analytically tractable dynamic stochastic model to investigate the effect of media monitoring on restraining large shareholders to expropriate minority shareholders welfare. In the research process, we first built a standard model to measure both large and minority shareholders welfare level under the assumption that expropriation and media supervision are both absent. Then we considered the optimal corporate dividend policy and large shareholders' optimal expropriation proportion in the presence of expropriation and quick and sharp decline of corporate assets created by media coverage. In the end, we analyzed the gains and losses of different interest

groups caused by expropriation and media supervision. The research found that large shareholders' expropriation on minority shareholders will affect the process in two aspects in the presence of media monitoring. One is the relocation of interest between large and minority shareholders, namely the Wealth Distribution Effect. Large shareholders raise their own welfare level at cost of decreasing minority shareholders' interest. The other is that large shareholders expropriation will lower corporate assets value, namely the Assets Impairment Effect. Because of the existence of media supervision, coverage on large shareholders expropriation will reduce corporate value, thereby impairing shareholders' interest.

■ TA-30

Tuesday, 8:30-10:00 - John Anderson JA5.02, Level 5

Simulation-Based Optimization

Stream: Simulation and Optimization
Invited session
Chair: *Leonidas Sakalauskas*

1 - Simulation-based approach for bilevel stochastic programming
Leonidas Sakalauskas

The sequential simulation-based approach has been developed to solve the stochastic bilevel equilibrium problems by finite sequences of Monte-Carlo samples. The approach considered is grounded by the stochastic termination procedure and the rule for iterative regulation of size of Monte-Carlo samples as well as taking into account the stochastic model risk. The rule introduced to regulate the size of Monte-Carlo sample inversely proportional to the square of stochastic gradient norm, allows us to solve stochastic bilevel problems rationally from the computational viewpoint and guarantees a.s. the convergence. The proposed termination procedure allows us to test the optimality hypothesis and to evaluate the confidence intervals of the objective and constraint functions in a statistical way. Application for pricing in the telecommunication network is considered. The numerical study and the practical example corroborate theoretical conclusions.

2 - Fleet Size and Mix Vehicle Routing Problem with Backhauls: A Random Successive Approximations Method
Javier Faulin, Javier Belloso, Angel A. Juan, Adrian Serrano, Elena Perez-Bernabeu

Fleet Size and Mix Vehicle Routing Problem with Backhauls (FSMVRPB) is introduced in Salhi et. al (2013). This variant is the combination of two well-known Vehicle Routing Problems where (1-FSMVRP) fleet is unlimited and composed by vehicles with different capacity, and (2-VRPB), nodes to be visited can receive materials from the depot (linehauls) or send materials to the depot (backhauls). A new methodology is presented using a successive approximations structure that is implemented through a multi-round logic. Each round, new solution is created by solving iteratively a number of homogenous Vehicle Routing Problems with Backhauls (VRPB) problems that coincides with the number of vehicle types. The optimal heterogeneous composition of fleet is obtained through a framework that guides the process and uses three randomised criteria. The first one is the selection of the order in which each type of vehicle is used, and the second one is the sorting of the savings list used to decide who the next customer to be visited. Once the type of vehicle is selected, the algorithm solves the homogeneous problem with the not-yet-visited customers considering an unlimited number of vehicles. The number of routes of this solution that will be part of final solution depends on the third random criteria. To verify the efficiency of our approach, we have used the benchmarks proposed in above reference, and initial results show promising solutions in a reasonable time.

■ TA-31

Tuesday, 8:30-10:00 - John Anderson JA5.04, Level 5

Airport Operations and Management

Stream: Stochastic Modeling and Simulation in Engi-

neering, Management and Science
Invited session
Chair: *Erik Kropat*
Chair: *Silja Meyer-Nieberg*
Chair: *Zeev (Vladimir) Volkovich*

1 - Robust Airport Gate Assignment
Fan Wang, Jinjia Huang, Zhou Xu

Airport gate assignment is to assign flights to gates according to the schedule, such that each flight is assigned to exactly one gate, and there is no conflict between two consecutive flights assigned to the same gate. In general, resource allocation with time window is concerned with service quality and stability. Concerning the mismatch between schedule and on-line flight time, robust airport gate assignment aims to protect the airport gate assignment from uncertainty such as flight delay or early arrival. Therefore, we propose robust airport gate assignment model, and consider some degree of variability in the flight arrival and departure time. The tractability of robust model is investigated and the equivalent binary linear programming counterpart has been derived. We further explore data-driven approach based on historical data. The experimental results on the real-life test data from Hong Kong International Airport demonstrate that our robust model incorporating data-driven approach is very competitive and obtains robust solutions of good quality.

2 - A comparative analysis of the pickup forecasting methods in airport carparks
Andreas Papayiannis

Accurate forecasts of customer demand lie at the core of any successful revenue management system. Most research focused upon studying such methods for the airline and hotel industry. In this paper, we focus upon the pickup forecasting methods; this family of methods uses relevant information from the reservation build-up process over time in order to construct the forecasts. By definition, these methods work by estimating the number of customers to come between two time points within the booking horizon. Implemented for the airport carparking (ACP) industry, our goal is to forecast customer arrivals and occupancy levels for one day to four weeks out in the future. Using real ACP booking data from two major UK airports, we present a comparative analysis of the pickup variants. Traditional techniques such as the weighted moving averaging schemes are tested on the underlying series, while more advanced methods such as ARIMA or seasonal-trend decomposition methods are also investigated. Conclusions are reached with regard to which forecasting methods perform best in this operating environment, and whether there is any benefit in employing complex methods over simpler ones.

3 - Air Traffic Control Officer (ATCO) Incapacitation
Victoria Chase, Simon Martin

Air Traffic Control Officer (ATCO) Incapacitation was a study that was carried out by NATS Ltd, the UK's leading provider of air traffic services.

The risks associated with incapacitation in ATCOs have never been previously systematically quantified and the medical rules applied to ATCOs are often derived from those applied to commercial pilots. The various roles performed by ATCOs vary significantly so the consequences of incapacitation in ATCOs will almost certainly vary depending on the circumstances.

Three different simulation exercises have been carried out and data from these has been combined to create a mathematical model to assess the risk of collision as a result of an ATCO incapacitation. This can inform future medical regulations in terms of quantitative incapacitation risk assessment.

4 - Computing Dynamic Revenue Management Controls to Maximise Revenue Subject to a Load Factor Constraint
David McCaffrey, Darius Walczak

We consider dynamic programming approaches to maximizing revenue from a single leg flight. This gives rise to dynamic bid price controls. We add a one-sided terminal cost to the dynamic program to penalize terminal states which fall below a user specified load factor target. The business challenge in utilizing such terminal costs is knowing how to trade off a given degree of deviation from a non-financial target such as load factor against a $ worth of revenue deviation. We compute an efficient frontier and use this to parameterize the terminal cost. We compare bid prices with and without the terminal cost, and assess performance and cost of meeting the load factor target via simulation results.

■ TA-32

Tuesday, 8:30-10:00 - John Anderson JA5.05, Level 5

AHP/ANP 05

Stream: Analytic Hierarchy/Network Process
Invited session
Chair: *Betül Özkan*

1 - A Fuzzy Multiple Criteria Decision Making Approach for Industrial Engineer Selection in Auto Components Industry

Derya Deliktas, Ozden Ustun

In this study, a fuzzy multiple criteria decision making approach is applied to the Auto Components Industry to select an industrial engineer among ten candidates. The industrial engineer selection problem has multiple criteria, hierarchical structure of those criteria and multiple decision makers. Also, the evaluation process of decision makers includes vague parameters. Fuzzy set is a powerful tool to cope with uncertainty caused by both the personal qualifications and the preferences of the decision makers. The subjectivity and vagueness in the candidates selection process is dealt with by using fuzzy numbers for linguistic terms. Triangular fuzzy numbers are used to convert the linguistic terms to fuzzy numbers. The industrial engineer selection problem seems appropriate to be modeled as fuzzy multiple criteria decision making problem. The fuzzy analytic hierarchy process method which makes us consider both tangible and intangible factors in an uncertain and vague environment is used to determine the weights for evaluation criteria by decision makers. The consistencies of pair-wise comparisons matrices are controlled by considering Consistency Index. A crisp overall performance value is obtained for each candidate based on the concept of Fuzzy Multiple Criteria Decision Making. The sensitivity of the candidates' overall performance value to both decision makers' weights and the weights of basis criteria is analyzed. Also, the candidates are evaluated by fuzzy TOPSIS.

2 - Wind Farm Siting Using a Spatial Analytic Hierarchy Process Approach: A Case Study of the Städteregion Aachen

Tim Hoefer, Yasin Sunak, Reinhard Madlener

Wind energy is one of the most important renewable energy sources in Germany. However, the diffusion of wind farms involves strong spatial effects in terms of landscape intrusion, noise level, and wildlife. Negative environmental impacts caused by suboptimal siting of wind farms have led to decreasing social acceptance on the local level. This paper aims at finding optimal locations for wind farm development and improving the siting assessment by using a holistic multi-criteria decision making approach that incorporates techno-economic, socio-political, and environmental criteria, which are defined in a way that social acceptance issues are specifically emphasized. We apply the Analytic Hierarchy Process, where a group of local experts is asked to pairwise compare the incorporated criteria in order to derive the relative importance of each criterion. This enables the identification of those sites that are characterized by a combination of technical efficiency, economic feasibility, environment compatibility, and - no less important - local social acceptance. The results obtained indicate that 9.4% of the study area is still available for wind energy development, whereas only 1.74% of the region is characterized by high suitability. In particular, the northern part of the region still offers substantial unexploited wind energy potential. A comparison with the location of existing wind farms and a sensitivity analysis validate the reliability and accuracy of the model results.

3 - Combining Smart Grid Management with Business Electricity Sustainability for Energy Utility Long-run Growth Outcome

Iberraken Fairouz, Medjoudj Rabah, Djamil Aïssani

This paper aims to provide knowledge to assist stakeholders in developing countries to understand the impacts of the integration of information and communication technologies (ICT) into the conventional network giving birth to a smart energy grid. The management of this latter is combined to electricity sustainability to achieve a long-run growth of a company ensuring production, transport and distribution of electrical power. We have investigated a multi-criteria decision- making method that allow aiding decision-makers (DMs) to learn about the advancements of developed countries in systems management and renewable energy resources (RES) insertion. The analytic hierarchy

process (AHP) is the method of our choice to make decisions, as it is judged a transparent process and a useful tool for conflicts resolution. For smart energy grid management, we have made an application to the Algerian conditions and the obtained results are very significant. Certainly, in both short and medium terms, the priority is given to the availability and the security of supply, but it is demonstrated that for the long term, electricity sustainability is an imperative to promote the human life. To highlight the high interest of AHP method, we have provided a comparison between the obtained results issued from AHP and MCDA methods applications to electricity sustainability in the case of Swedish power system, as this issue is sustained by the European's concept of smart grids.

4 - Evaluating Risks in a Pharmaceutical Supply Chain by Using Type-2 Fuzzy Analytic Hierarchy Process

Betül Özkan, Huseyin Basligil

A supply chain faces with different types of risks during its processes. A pharmaceutical supply chain is one of the supply chains that consists many critical risk factors. Because of its complex and complicated nature, occurred risks can directly affect human health. So, it is very important to define and evaluate these risks carefully. The most critical risks should be minimized primarily. In this study to determine the weights of risks and prioritize them, a combined approach of type-2 fuzzy sets and Analytic Hierarchy Process (AHP) is used. Firstly, potential risk factors that can occur in a pharmaceutical supply chain are determined. To deal better with uncertainty, type-2 fuzzy sets are used for evaluation of risks. The weights of risks are determined by using type-2 fuzzy AHP and they are prioritized according to their weights. Finally, the most critical risks that should be minimized primarily are determined.

■ TA-33

Tuesday, 8:30-10:00 - John Anderson JA5.06, Level 5

Quality Control

Stream: OR in Quality Management
Invited session
Chair: *Ipek Deveci Kocakoç*
Chair: *Gul Okudan Kremer*

1 - Multivariate Profile Monitoring When Process Variables are Prone to Change

Amitava Mitra, Shovan Mishra

The traditional approach of monitoring output variables uses a scaled distance measure based on the mean and variance-covariance matrix associated with the output variables. The process variables are assumed to be fixed. Here, we present a generalized measure, which will identify outliers in the expanded space of the process variables as well as the output variables. Through a simulation approach, the performance of the proposed measure is explored when the process regulatory variables and/or the noise factors are perturbed from their initial states. The performance measure used is the time to first detection of out-of-control conditions, as measured by its mean and standard deviation. The proposed measures performs quite well in its power to detect out-of-control conditions.

2 - Some control charts for exponentially distributed quality characteristics

Chi-Hyuck Jun

Control charts are usually designed by assuming that the quality characteristic of interest follows a normal distribution. In practice, however, some quality characteristics may not follow a normal distribution but follows a skewed distribution. Sometimes, an exponential distribution is better fitted to a skewed quality characteristic such as lifetime of a component and waiting time until an event occurs. In this study, we consider several control charts for an exponential distribution by considering variable transformation leading to a normal approximation. Three control charts are proposed here, first one using a EWMA statistic, second one using repetitive sampling and third one using multiple dependent state sampling. The average run lengths are evaluated for the performance measure. The out-of-control average run lengths are calculated and compared according to shift constants in the scale parameter of the exponential distribution. It is shown that these proposed control charts for an exponential distribution detects a shift, if any, more quickly than the existing control chart.

3 - Fault detection of a multi-profile data with a correlation using Hotelling's T2 Control Chart

Dong Hwan Kim, Seung Hwan Park, Jun-Geol Baek

Modern manufacturing processes generate a wide variety of profile data from tens of hundreds of sensors. The profile data has a different pattern for each sensor to be measured. The profile data has a certain period and the step length of each process stage. And it has also a different pattern according to the measurement sensor. In this situation, data processing is difficult in general because they do not meet the statistical assumptions, such as the normal distribution. It is also difficult to analyze simultaneously because the existing building control charts manage for each profile data, and to have to build a lot of charts for each sensor. Furthermore, there is also a tough challenge to take into account the correlation between the characteristic of the profile data of the individual charts. In this study, in order to overcome these problems, we propose a method to build the individual multivariate control chart to manage the profile data of different types at the same time and detecting the presence of fault profile in the process according to the time. We use the simulation data imitating the actual process for security reasons. Using a variety of profile data to create a Hotelling's T2 values for each point, we use them to create a new control chart. Finally we compare the proposed control chart to the individual control chart of an each profile data, and analyze for results.

■ TA-34

Tuesday, 8:30-10:00 - John Anderson JA5.07, Level 5

Realistic Production Scheduling 2

Stream: Realistic Production Scheduling
Invited session
Chair: *Nhat Vinh Vo*

1 - A Study on the Dominance Between Lower Bounds in a Flowshop Scheduling Problem by Vo and Lenté

Nhat Vinh Vo, Christophe Lenté

In this presentation, we are interested in flowshop scheduling problems with several additional constraints based on time lags, non-sequence dependent removal/setup times, blocking, tails and release dates. A family of lower bounds for the total weighted completion time of these problems is elaborated in a previous study [Vo and Lenté, 2014]. In this study, each lower bound is calculated by solving an ATSP and a lower bound selection strategy is applied to this family in order to accelerate the branch-and-bound procedure. The strategy was designed according to the dominance between lower bounds over a certain number of nodes. This current study aims at modifying the strategy by investigating the dominance between lower bounds over each level of the branch-and-bound procedure. We also study the impact of the number of jobs and that of the nature of tested instances. A smarter lower bound selection strategy is then conducted. As a result, computation times of the branch-and-bound procedure are expected to be shortened. [Vo and Lenté, 2014] From MaxPlus algebra to general lower bounds for the total weighted completion time in flowshop scheduling problems. Lecture Notes in Management Science, 6:128—137 : ICAOR 2014. ISSN 2008-0050 (Print), ISSN 1927-0097 (Online).

2 - A Heuristic for Batching and Scheduling Composite Production in Parallel Ovens

Burcu Cansu İnanç, Kadir Ertogral, İlay Şenköylü

Usage of composite material is the best way of weight reduction in aircraft industry and this is why the leading aircraft producers, such as Boeing and Airbus, focus on new development and production methods for composite materials. Our study is about scheduling curing process in ovens, called autoclaves, in the composite department of a major producer from aerospace industry in Turkey. The composite parts go through the curing process in batches which are compatible in terms of some process parameters, such as temperature and pressure. The scheduling problem involves grouping of the composite parts into batches and then assigning them to one of the multiple autoclave ovens, while obeying several restrictions including satisfying all demand on time. The adopted objective in the study is the minimization of the energy consumption in the ovens. We suggest both a mathematical formulation of the problem and an efficient heuristic for the solution. We demonstrate the performance of the heuristics on a set of problems obtained from real life production data.

3 - Minimization of Open Stacks Problem: Some Properties of the Solutions

Horacio Yanasse

We focus on the Minimization of Open Stack Problem (MOSP) that arises, for instance, in cutting settings. In MOSP we seek a sequence to cut a set of patterns in a saw machine so that the maximum number of open stacks is the least possible. Each type of item cut opens a stack that remains opened until the last item of that type is cut. We present some properties of the solutions of MOSP that can be explored in the development of new methods with potential improvements in terms of quality of the solutions generated compared to existing methods.

4 - Modified Dynamic Programming Algorithm for Solving the Job Shop Scheduling Problem

Ansis Ozolins, Svetlana Asmuss

In the job shop scheduling problem (JSSP), as it is considered in this work, each job have to be processed by a given number of machines. The jobs cannot overlap in the machines and each machine can process only one job at a time. We deal with the case where the objective is to minimize the total makespan, i.e. the time needed for processing all jobs. We modify the exact dynamic programming (DP) algorithm given by J.A.S. Gromicho et al. by including additional restrictions which reduce the state space. In this framework we consider several benchmark instances. We also propose the modification of the DP algorithm to obtain co-optimal solutions for the JSSP. Furthermore, some special variants are developed, e.g. JSSP involving maximum time lags between operations, JSSP with due dates, job shop with no-wait problems where each operation of a job must start directly after its preceding operation has finished. This research has been partially supported by ESF project 2013/0024/1DP/1.1.1.2.0/13/APIA/VIAA/045.

■ TA-35

Tuesday, 8:30-10:00 - Colville C429, Level 4

Education and Health Care

Stream: DEA and Performance Measurement
Invited session
Chair: *Maria Portela*

1 - How to tackle the endogeneity problem in DEA? An application with educational PISA data

Daniel Santin, Gabriela Sicilia

Selecting the appropriate input and output variables to include in the DEA model is the most critical decision for practitioners in order to obtain reliable efficiency scores. However, there is another major concern, namely, the presence of endogeneity in the production process, which is frequently overlooked when practitioners apply DEA even though it is an issue that has received plenty of attention in econometrics. In a recent work Cordero, Santín and Sicilia (2015) analyse the distortions in the DEA estimates caused by high positive endogeneity. That is, when at least one input in the production process is positively correlated with the true efficiency level. Therefore, two key issues emerge now: how can be endogeneity detected in empirical analysis and how can this problem be overcome in DEA applications. These are the aims of the present research. To do this, we use synthetic data generated in a Monte Carlo experiment to compare different endogenous scenarios with an exogenous one. As a result, we propose a simple statistical procedure which allows practitioners to identify the presence of an endogenous input in an empirical application. In addition, we evaluate a potential solution to deal with this problem in order to improve DEA estimations through an "instrument input'. The results evidence that this option significantly improve DEA estimates. Finally, we perform an empirical application in the education sector in order to illustrate our theoretical findings.

2 - Technical Efficiency Analysis of Undergraduate Career in Higher Education in a Series of Time

Gonzalo Eduardo Campos Hernández

Currently in Chile, the government is pushing a radical educational reform, which involves deep structural changes at the secondary education and tertiary (University/College) level. This study developed and integrated methods that permitted us to evaluate the technical efficiency of majors in higher education over a 10-year time period, which permitted a detailed analysis of which units (majors) are using their

resources efficiently in order to provide performance indices and suggestions to improve the processes of inefficient units. For this study, variable selection methods were created over time, and then DEA Window Analysis models were applied to the majors, Finally technological changes were analyzed over time. As a result, a set of indicators was created to facilitate the measurement and comparison over the time that the resources of homogeneous groups of decision units are used, as a good way to manage the available resources and make decisions based on the results.

3 - Identifying the Scope for Savings At Inpatient Episode Level: An Illustration Applying DEA to Chronic Obstructive Pulmonary Disease
Maria Portela

Chronic obstructive pulmonary disease (COPD) is characterized by a largely irreversible obstruction of the airways, and is one of the leading causes of chronic morbidity and mortality worldwide. This paper illustrates the use of Data Envelopment Analysis (DEA) to assess the potential for savings at COPD inpatient episode level. The analysis uses the length of stay of each episode as a surrogate for expenditure on that episode while allowing for the medical condition of the patient and the quality of care received. Results point to substantial possible reductions in length of stay which could translate to cost savings. The paper also explores differences both between providers and within providers in potential for length of stay reductions so that cost efficient protocols of treatment can be identified and disseminated.

■ TA-36
Tuesday, 8:30-10:00 - Colville C430, Level 4

Teaching OR/MS I

Stream: Teaching OR/MS
Invited session
Chair: *José Fernando Oliveira*

1 - Teaching OR to Undergraduate Management Students: the role of Gamification
Joana Matos Dias

Gamification is the use of game thinking in contexts that do not have anything to do with games. It has already been successfully applied in several educational environments, and it can also be helpful in OR education. It contributes to keep the students motivated and engaged. Some experiments will be described and results presented.

2 - Fit for purpose? - As assessment of postgraduate education in Operational Research
Jana Ries, Alessio Ishizaka, Dylan Jones, Ashraf Labib

The talk will discuss the match of current Master programmes with industrial requirements in the profession of an Operational Researcher. Hereby, insights will be given on similarities and differences of the structure of Master Programmes in Operational Research in the UK and Europe, whilst analysing industrial and academic job requirements and core abilities in the field of OR. Various key factors will be discussed, including the concept of core OR skills in research and industry.

3 - A project-based learning Logistics course
Maria Antónia Carravilla, José Fernando Oliveira

We will present the implementation of a project-based learning Logistics course. The course is organised in three blocks, with an initial block for set-up and training, a one-week block in the end for student's cross-evaluations (accounting for 25% of the final grade), and a main central block divided in 5 main topics. Students are organised in teams that are assigned by the teachers and change for every topic. The grades for the team work are shared by the teams. Each team has a leader and each student is leader at least once during the course. All students are assessed by their peers for their contribution for the team in the several groups and for their leadership work. The period for each topic is dedicated to student research work involving different perspectives of the same topic: basic concepts; strategic approaches; quantitative approaches. The final output of each two-week work is a class where all groups make a presentation, focusing specially on the

assigned perspective. These presentations are prepared one week in advance in a leaders meeting, with the teachers, to discuss the plans for the presentations, discuss task division within teams, discuss difficulties, eliminate overlaps and decide the sequence of the presentations. The assessment involves also a final exam, with a weight of 25% on the final mark. The model is quite appraised by the students, who contribute for its improvement by answering an anonymous questionnaire.

4 - Squaring the circle: a distributed, individual, formative, evaluation model for large groups of students.
José Fernando Oliveira, Maria Antónia Carravilla

In this talk a teaching-learning model, with individual, distributed and formative assessment method will be presented. It is applied to undergraduate Operational Research courses on three programmes, involving a total of 340 students. In particular the distributed assessment methodology will be described, including the student feedback mode and the supporting all-in-on class model, which has a relevant collaborative learning component. The results of the implementation of this model are assessed with a longitudinal study, controlling and eliminating the other possible causes for the achieved results improvement, as a statistically significative increase on the average grades was observed.

■ TA-37
Tuesday, 8:30-10:00 - Colville C411, Level 4

OR for Sustainable Built Environment

Stream: OR for Sustainable Development
Invited session
Chair: *Vida Maliene*

1 - Multiple criteria decision making (MCDM) methods' application in land and property management
Vida Maliene

Traditionally Multiple Criteria Decision Making (MCDM) methods have been widely used in Business Management and Civil Engineering. However, in recent years the MCDM methods have been successfully applied in various areas of property, land management and built environment related research. The turn of the 21st century marks significant changes and development processes in land and property management and valuation, which are being constantly affected by legal, economic and social conditions. Stakeholders are constantly facing a pressure on decision making for sometimes very complex projects. MCDM is a number of methods which deal with the evaluation of a set of alternatives in terms of numerous, often conflicting, decision criteria (Triantaphyllou 2000). Thus, given a set of alternatives and a number of criteria, MCDM aims to assist in identifying the best alternative or a ranking of the alternatives. MCDM methods are useful in supporting decision making problems where conflicting objectives are involved, especially economic, environmental, social, and politic (Maliene et al., 2010; Maliene, 2011). Several MCDM methods' application in land and property management practice will be introduced during the presentation.

2 - Strategy modelling for hotel facilities management
Rasa Apanaviciene, Silvija Kapočiene, Nerijus Varnas, Ala Daugeliene

In many countries hotels represent a significant part of real estate sector. Hotel competitiveness is influenced by effective business as well as rational facility management solutions that allow reducing overhead and direct operating costs. While analysing external/internal factors and peculiarities of facilities management process, the theoretical model for hotel facilities management solutions was developed, that combines market, service supply chain, facilities management efficiency criteria, as well as economic, expert and multicriteria evaluation methods. By applying the proposed model in practice, the optimized hotel facilities management strategies might be generated.

3 - Application of multi-criteria methods for brownfields' prevention
Vytautas Bielinskas, Marija Burinskiene

In the previous study conducted by the authors on the basis set out in the "early' brownfields' indicator system in Lithuanian city areas concludes a framework for an experimental study in Vilnius city in accordance with the administrative division of the territories-elderships. For the purposes of multi-criteria assessment methods and mathematical statistics to identify brownfields indicators describing the changes in value over time and their influence on the formation of brownfields. Depending on the stage of brownfield indicators describing the changes, their negative or positive impact on the determined critical indicator of the range of variation and selection of the means and methods that can ensure the prevention of brownfields. Implementing monitoring of territories, following their indicators and applying preventive measures, and in accordance with the selected application sequence urban areas would be protected from formation of brownfields.

■ TA-38

Tuesday, 8:30-10:00 - Colville C410, Level 4

Humanitarian Operations Research

Stream: Humanitarian Applications
Invited session
Chair: *Erik Kropat*
Chair: *Silja Meyer-Nieberg*
Chair: *Karen Fryer*

1 - Using OR Models to Create International Standards in Disaster Planning
Duncan Shaw

This paper reports on a project about developing OR models for mass evacuation planning. The models were based on 142 interviews with senior emergency planners from 10 countries. Through analysing the interviews we identified key variables to inform the structure of the OR models. The paper discusses the process of identifying the variables and why the OR models were not implementable in the countries. To ensure impact of the work, the variables were used to develop an international standard on mass evacuation planning that has OR modelling at its heart. The paper will show how the standard (now published by the International Standards Organisation [ISO]) was written based on the OR models. The paper will also report on another standard on the involvement of convergent volunteers in disaster management that is 'in progress' with ISO, again based on OR models.

2 - Routing and Scheduling of Rail Transportation for Hazardous Materials
Ginger Ke, Kan Fang, Manish Verma

This paper investigates the routing and scheduling of rail shipments of hazardous materials in the presence of due dates. In particular, we consider the problem of minimizing the weighted sum of earliness and tardiness for each demand plus the holding cost at each yard, while forcing a risk threshold on each service leg at any time instant. The US Federal Railroad Administration accident records, between 1999 and 2013, were analyzed to establish that train speed was the most significant factor in derailment. A mixed-integer programming model and two heuristic-based solution methods are proposed for preparing the shipment plan. Finally, the analytical framework is used to study and analyze a number of realistic-size problem instances generated using the infrastructure of a Class I railroad operator.

3 - Continuous Improvement in Humanitarian Supply Chains
Karen Fryer

Research into humanitarian supply chains is becoming more widespread (e.g the establishment of the Journal of Humanitarian Logistics and Supply Chain Management Journal in 2011). Kovacs and Spens (2011) in looking at the gaps in humanitarian logistics research, identified continuous improvement as an area that needed further research. Pettit and Beresford (2009) had previously identified continuous improvement as one of the critical success factors for humanitarian aid supply chains.

Continuous improvement (CI) is at the heart of lean improvement and a key element of many self-improvement frameworks such as the EFQM Business Excellence framework. It has long been argued that it takes time and management commitment to implement CI successfully

(Fryer et al, 2013). The underlying principles of making small changes initially appear to be more suited to a "steady-state' organisation rather than the more fluid environment of humanitarian supply chains. Abidi et al (2014) stated that it is increasingly important for humanitarian organizations to measure and manage performance which is an essential element of continuous improvement.

The purpose of this paper is to establish a theoretical basis for measuring continuous improvement in humanitarian supply chains

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■ TA-39

Tuesday, 8:30-10:00 - Colville C405, Level 4

Applications in Multi Criteria Decision Making & Decision Analysis

Stream: Decision Support Systems
Invited session
Chair: *Fatima Dargam*

1 - Mulcriteria Decision Analysis for Bank Risk Assessment
Pascale Zaraté, Jean Baptiste Rakotoarivelo, Josvah Paul Razafimandimby

This work aims to observe a better choice for risks evaluation Financial organisms. Our aim is to support banks during operations of customers with respect to funding opportunities, investment or credits reaching. First of all, we identify different types of risks associated with this activity and we secondly analysed them thanks to a method of multi-criteria analysis AHP (Analytic hierachy Process) with different means adopted to identify them. It should be noted that a financial institution is risky and it is in no case possible to annihilate full all sources of risk. Was examined certain types of risks inherent in this activity, these risks are grouped into four criteria such as operational risk, financial risk management, risk against parties and external risks. Although professionals in risk management are trying to better understand the risks and they use to do this complex models, but many of the risks are still not well understood. Therefore, this work has contributed to the resolution of risk, and deliver results that will allow the institution to address the factors that may prevent the achievement of its objectives.

2 - A Decision Support System for New Product Portfolio Management - Hybrid DEA Model
Kiranmayi Pulipaka, Muthu Mathirajan

New Product Management (NPM) is associated with higher degree of risk and uncertainty due to lack of information, challenging constraints to allocate limited set of resources and lack of time because of increased global competition. Though in literature there are attempts to model Project Evaluation and Selection(PES) for New Product Portfolio(NPP), these studies did not consider multiple objectives like achieving balance among projects, project interdependencies, resource optimisation and strategic alignment. To extend our scope of research beyond literature review, we studied PES process of NPP in manufacturing industries through case studies. Based on implications from case study we develop and demonstrate a Decision Support System (DSS). The objectives considered in the constructing DSS is to select a set of projects for NPP satisfying: (a) strategically aligned with organisation goals and vision (b) balance between innovation level, risk level, cost and resources (c) optimally the resource allocation by consideration of interdependencies (d) efficiently estimate risk and uncertainty and (e)accurately estimate cost and benefits. The proposed DSS is based on concepts of improvised balanced scorecard (BSC) approach,Bayesian Networks,Cost Benefit Analysis which are integrated together with the help of weighted data envelopment analysis (DEA). In this paper,the proposed DSS is implemented in MATLAB and workability is demonstrated by developing suitable numerical example.

3 - Designing and building with MACBETH a value risk-matrix for evaluating occupational health and safety risks
Diana F. Lopes, Monica Oliveira, Carlos Bana e Costa

Risk matrices (RMs) are commonly used to evaluate occupational health and safety (OH&S) risks. Departing from the RMs' methodological problems, this study describes how multiple criteria decision

analysis methods have been used to improve the design and the deployment of RMs to evaluate OH&S risks at the Occupational Health and Safety Unit (OHSU) of the Regional Health Authority of Lisbon and Tagus Valley. A 'Value risk-matrix' was built with the OHSU by using the MACBETH approach, being then implemented in a decision support system to evaluate OH&S risks and to identify risk mitigation actions.

4 - How Many Crowd Workers Should a Requester Hire on Amazon Mechanical Turk?
Arthur Carvalho, Stanko Dimitrov, Kate Larson

Recent years have seen an increased interest in crowdsourcing as a way of obtaining information from a large group of workers at a reduced cost. The crowdsourcing process, as we consider in this work, is as follows: a requester hires a number of workers to work on a task. After completing the task, each worker reports back an output. The requester then aggregates the reported outputs to obtain a collective output. A crucial question that arises during this process is: how many crowd workers should a requester hire? In this work, we investigate the optimal number of workers a requester should hire on the crowdsourcing platform Amazon Mechanical Turk. In particular, we report the results of three studies involving different tasks as well as different payment schemes. We find that both the expected error in the aggregate output as well as the risk of a poor combination of workers decrease as the number of workers increases. Surprisingly, we find that the optimal number of workers a requester should hire for each task is around 10 to 11, no matter the underlying task and payment scheme. To derive such a result, we employ a principled analysis based on segmented linear regression. Besides the above result, we also find that top-performing workers are more consistent across multiple tasks than worst-performing workers. Our results thus contribute to a better understanding of, and provide new insights into, how to design effective crowdsourcing processes.

■ TA-41
Tuesday, 8:30-10:00 - Colville C512, Level 5

Spatial Multicriteria Evaluation: Insights and Applications I

Stream: Multiple Criteria Decision Aiding
Invited session
Chair: *Valentina Ferretti*
Chair: *Gilberto Montibeller*

1 - Decision Analysis with Geographically Varying Outcomes: Preference Models and Applications
L. Robin Keller, Jay Simon, Craig Kirkwood

This paper presents decision analysis methodology for decisions based on data from geographic information systems. The consequences of a decision alternative are modeled as distributions of outcomes across a geographic region. We discuss conditions which may conform with the decision maker's preferences over a specified set of alternatives; then we present specific forms for value or utility functions that are implied by these conditions. Decisions in which there is certainty about the consequences resulting from each alternative are considered first; then probabilistic uncertainty about the consequences is included as an extension. The methodology is applied to two hypothetical urban planning decisions involving water use and temperature reduction in regional urban development, and fire coverage across a city. These examples illustrate the applicability of the approach and the insights that can be gained from using it.

2 - Planning and Design Support Systems for Urban Walkability
Ivan Blecic, Arnaldo Cecchini, Giovanna Fancello, Giuseppe Trunfio

We present a methodology and a planning and design support system for evaluating walkability of places, which is an important component of quality of life in cities. A spatial multicriteria evaluation model is used to assign walkability scores to points in urban space. We derive the scores from potential pedestrian routes along the street network, taking into account the quality of urban space on several attributes relevant for walkability. One of its notable characteristics is a certain

reversal of perspective in evaluating walkability: the walkability score of a place does not reflect how that place is per se walkable, but instead how and where to can one walk from there, that is to say, what is the walkability the place is endowed with. This evaluation incorporates three intertwined elements: the number of attractive destinations reachable by foot, their walking distances, and the quality of the paths to these destinations. We further show possible uses of the support system by discussing the results of a case-study assessment for the city of Alghero in Sardinia. We also explore a possible development of an urban design support tools centred on walkability where the system itself generates hypotheses of projects, given some (user-provided) objectives and constraints. There seems to reside a potential for developing not only evaluative, but also such generative procedures, in other words, to develop not only tools for assessing projects, but for designing them.

3 - Spatial multi-criteria evaluation for regional planning in less developed countries: lessons from reconstruction in Darfur and national urban planning in Rwanda.
Luc Boerboom

Understanding the available functions and structures, or lack thereof, in urbanizing settlements, is an essential basis for public and private investments. These functions and structures, should not be seen in isolation, but in regional context. UN Habitat, the human settlements program of the United Nations, in collaboration with a number of partners, has recently developed a method called the Spatial Development Framework. This method plans for urban investment based on understanding of settlements in their regional context. One of the methods used within the Spatial Development Framework is spatial multi-criteria evaluation (SMCE).

SMCE evaluates the functions and structures in settlements and in their regional context, based on a multi-dimensional analysis on themes such as economic development potential, infrastructure, or healthcare. This paper presents the role of SMCE in two cases. The first case is for regional reconstruction of the war-torn region of Darfur in Sudan. The second case is for implementation of a national urbanization policy in Rwanda. This role will be described both in terms of the technical analysis, the process of investment planning and the relation between these two. The description of these two cases provides a number of lessons regarding the use of spatial multi-criteria evaluation for regional planning in less developed countries.

4 - Multi-Criteria Spatial Risk Analysis
Valentina Ferretti, Gilberto Montibeller

Allocating scarce resources against natural hazards, such as flooding, erosion, and earthquakes, poses several challenges to policy makers: (i) the presence of multiple stakeholders with often conflicting objectives, (ii) the need for transparency and justification due to the public nature of such decisions, (iii) the presence of multiple impacts with different spatial distributions, (iv) the assessment of spatial vulnerabilities, (v) long time horizons, and, finally, (vi) the need to take into account uncertainties about impacts and the probability of spatial occurrence of events. Recent developments in spatial multi-criteria analysis have enabled the assessment and aggregation of multiple impacts, supporting policy makers in spatial evaluation problems. However, despite the relevance of the approach for risk analysis modelling, recent attempts of conducting spatial multi-criteria risk analysis have so far been poorly conceptualised, without adequate roots in quantitative risk analysis. On the other hand, current attempts of assessing spatial risks have neglected the multi-dimensional nature of spatial impacts (for example, social, economic, human) often present in such decision problems. This paper aims at exploring how we could conceptualize a quantitative framework for spatial risk analysis to support both the evaluation of vulnerabilities and impacts in this context and the allocation of scarce resources for countermeasures.

■ TA-42
Tuesday, 8:30-10:00 - McCance MC301, Level 3

Case studies in OR/Analytics 3: Effective Basic Analysis

Stream: Case Studies in OR / Analytics
Invited session
Chair: *John Ranyard*

1 - Using Regression Analysis and Modelling to Underpin Lifesaving Interventions

Michael Wright, Joseph Breen, Cath Reynolds, Russell Hocken

The RNLI has undertaken an innovative regression analysis of incident data in order to develop an understanding of the factors that affect their lifesaving activity. The work forms part of the RNLI's strategy to save lives at sea. It represents a leading edge approach to the use of data to inform decision making.

The regression analysis identified factors such as wind, the type of incident, sea water temperature, visibility and response time affect the outcome of services. A computerised statistical model and Geographical Information System of community safety activity is now being developed, to assist with deployment decisions and strategic planning.

This paper will describe the underpinning analysis work and how this is being developed into a strategic decision making model for use by RNLI to inform their work in the future.

2 - International Students in the UK: Trends and Prospects

Paul Randall

In recent years, the UK Higher Education (HE) sector has faced a period of exceptional change, notably in its financing arrangements and in the immigration regime for overseas students. A major charity, providing accommodation and support services for (mainly) overseas students was considering a substantial capital investment to increase its capacity. The future success of that investment depended critically on both on the numbers of overseas students studying in the UK and the continuing viability of HE institutions. A pro bono OR project analysed data, and other forms of information, from a range of sources. Its report on the risks to future overseas student numbers informed the Board decision on the proposed investment. It subsequently formed the trigger for further Government analysis of prospects for the HE sector

3 - Construction and Evaluation of Spreadsheets used in Governmental Funding Formulae

Paul Hewson

Funding formulae are commonly used by central government in order to allocate money to subunits responsible for the delivery of services. One attraction of such an approach is that it appears objective and free from narrow political influence. Funding formulae can be developed in order to meet stated political goals, such as equity in service delivery or equity in outcomes. However, in a complex public service there can be many competing aims and goals. Funding formulae could potentially allow transparency in the way in which different aims are prioritized. We will review funding formulae as used by Police and Fire and Rescue Services in England. We will specifically focus our attention on the way simple OR methods for evaluating the behavior of spreadsheet models can provide insight into the behavior of the funding formula. Hence we will consider the extent to which specific policy goals are actually met by a specific funding formula.

■ TA-43

Tuesday, 8:30-10:00 - McCance MC303, Level 3

Defence and Security Applications V

Stream: Defence and Security Applications
Invited session
Chair: *Ana Isabel Barros*

1 - Optimising Emergency Preparedness and Resource Utilisation in Mass Casualty Incidents

Dimitris Paraskevopoulos, Panagiotis Repoussis, Alkis Vazacopoulos, Nathaniel Hupert

This work is concerned with the development of a response model in the aftermath of a Mass-Casualty Incident (MCI). A rigorous mixed integer programming (MIP) formulation is proposed for solving the combined ambulance dispatching, patient-to-hospital assignment, and treatment ordering problem. Towards solving the problem, MIP-based construction heuristic and iterative local search metaheuristic algorithms are developed. The objective is to minimize the time required to provide emergency treatment to all patients. The proposed model is

challenged on the hypothetical case of a terror attack at the New York Stock Exchange in the Lower Manhattan with up to 150 trauma patients. The bottlenecks for various capacity settings are identified, in terms of the number of ambulances and available hospital beds, while the effect of including remote hospitals as opposed to reduced ambulance transportation times is illustrated.

2 - Enhancing Information Security Expenditure Decisions by the use of a Decision Support System

Hannah Louise Davies

As Information Security becomes a more discussed topic, the ways in which organisations are ensuring the safety of their Information also becomes a topic in the foreground, and there are severe penalties for organisations that are unable to guarantee security for their customers, or stakeholders. There are a number of Information Security solutions available to organisations, from simple off the shelf anti virus software to advanced firewalls. The selection of a Security solution that is both appropriate for the organisation, in terms of the threats it is likely to sustain and the nature of the organisation, as well as being cost effective, is a problem that needs addressing. Current methods to evaluate financially the different Information Security solutions are very subjective, unpredictable and non repeatable. The methods are ad-hoc and not standardised. The application of Multi Criteria Decision Making, namely Multi Attribute Utility Theory and fuzzy and grey theory can create a decision support system for assessing the suitability of an Information Security solution. The large number of metrics, with different units and degrees of accuracy can be handled. This work presents a novel decision support system that makes use of Multi Attribute Utility Theory that incorporates fuzzy and grey theory to handle uncertainties and incomplete information in order to better evaluate Information Security solution expenditure.

3 - A new approach to modelling Cyber Defence based on a Rule Based Fuzzy Cognitive Map

Pawel Zdanowicz, Dobrila Petrovic, Colin Irwin, Stephen Lucek

This paper presents a new approach to modelling Cyber Defence within large organisations. There is a desire to have a high level understanding of the Cyber domain problem in order to inform strategic decisions to achieve effective and efficient Cyber Defence funding. However, relationships between Cyber Defence concepts cannot be easily defined using mathematical formula and the relevant knowledge is of a qualitative nature. A Rule Based Fuzzy Cognitive Map (RBFCM) is developed to model core, high-level, Cyber Defence functions (e.g. ASSESS, PROTECT, DETECT, and RECOVER) and their sub-activities, modelled as nodes. These are represented in terms of intangible attributes (e.g. Understanding, Ability, Availability, Risk, Intent). The nodes are related through a complex, non-linear, net of dependencies that spans the Cyber Defence functions. The qualitative relationships between nodes are defined using IF-THEN rules, which describe how one "effect' node is impacted by a change in another "causal' node. A new reasoning mechanism is developed to determine the impact of a change in one node on the whole system. It includes algorithms for firing rules and determining the resulting impact, accumulation of impacts and handling complex IF-THEN rules. The RBFCM model can be used to analyse an impact of different strategic investments, in the first instance to investigate the behaviour of Risk to the Business under six different investment scenarios.

4 - Advancing State of the Art in Applying Network Science to C2

Herman Monsuur, René Janssen, Tim Grant

Modern C2 systems link tens of thousands of computers and their users. Network science provides the mathematical techniques for representing and analyzing networks with millions of nodes. C2 has been making a transformation from top-down, directive command to Network Enabled Capability (NEC), self-synchronization, and agility. Therefore C2 systems are regarded as networks, rather than a hierarchy. It is appropriate to view these processes and systems through the lens of network science. The goal of the presentation is to outline recent advances in the state of the art of applying network science to C2.

■ TA-44

Tuesday, 8:30-10:00 - McCance MC319, Level 3

Fuzzy Decision Analysis

Stream: Fuzzy Decision Support Systems, Soft Computing, Neural Network
Invited session
Chair: *Martin Gavalec*

1 - Best consistent approximation of a fuzzy preference matrix
Martin Gavalec

In multi-criteria decision problems the Analytic Hierarchy Process (AHP) is often used. The AHP method is based on a structured model of the problem, where several alternatives and criteria are considered. The relations between the various possible alternatives according to given criteria are quantified by the matrix of fuzzy relative preferences. The preference matrix is mostly prepared by human experts, and some inconsistencies of the entries often occur. A method for computing the best consistent approximation of a (possibly inconsistent) fuzzy preference matrix will be described in the lecture. First a characterization of the consistent matrices in the additive form is given. Then the computation is formulated as a linear optimization problem, and an efficient algorithm for computing the optimal consistent approximation of a given inconsistent preference matrix is suggested. The method is demonstrated on numerical examples.

2 - Modified ROC — reflecting different types of misclassification
Jan Stoklasa, Jana Talasova, Pasi Luukka

In social sciences, e.g. in psychology, the mathematical classification needs to deal with an important issue — deliberate distortions of data. It is usual to build or train the classifiers on "good examples' (which can be analogical to diagnostics criteria) or high quality data (not deliberately distorted). When such classifiers are then used in practice, misclassification can be caused by a flaw in the design of the classifier (its poor performance) or by the fact, that the particular piece of data (psychological test result) has been distorted by the person providing the (to look more healthy or ill). These types of misclassification should be treated differently in the process of assessing classifier quality. The fact that the data are interpreted correctly by the classifier, but do not reflect the characteristics of the given person, should be reflected. Measures of data distortion (quality) can be found in diagnostics tools. Various measures of mathematical classifier performance have been designed, but as far as we know, none of these reflects directly the quality of the data. We propose a fuzzification ROC analysis that regards misclassifications of data instances with high quality of data as more serious than misclassifications of instances with lower data quality (=distorted data). We discuss possible benefits of its use on artificial data and present an example of its application on a real life fuzzy rule base classifier from psychological diagnostics.

3 - Evaluation of absolute type in the models of multiple criteria decision making
Jana Talasova, Vera Jandova

In most decision making models described in literature, evaluations of relative type are applied. If the aim of decision making is to choose the best from a set of alternatives, then the evaluation of relative type is sufficient. But there are also other decision making tasks, e.g. decision making about granting a credit in banking, when it is necessary to know how much each alternative fulfills the given goal of the evaluation. Evaluations of absolute type (with respect to a given goal) are measured on the scale of absolute type. The closed interval [0,1], where 0 means that the goal in not fulfilled at all and 1 says that the goal is absolutely fulfilled, can serve as an example of such scale. Application of the evaluation of absolute type will be illustrated by the Partial Goals Method (both in its crisp and fuzzy version). The method is based on the following concept: The overall goal of evaluation is decomposed into partial goals. Partial evaluations of alternatives with respect to the partial goals are given as measures of fulfillment of the goals. Normalized weights of the partial goals express their shares in the overall goal. It will be demonstrated that the overall evaluations calculated as corresponding weighted averages of the partial evaluations express measures of fulfillment of the overall goal. A fuzzified version of the Partial Goals Method that is implemented in the FuzzME software tool will be presented, as well as other similar methods of FuzzME.

4 - Decision Matrices with Fuzzy States of the World
Ondřej Pavlačka, Pavla Rotterová

A decision matrix is a common tool for solving decision-making problems under risk. Elements of the matrix express degrees of a decision-maker's satisfaction if he/she chooses the particular alternative and the particular state of the world occurs. In real world decision-making problems, we often meet vaguely described states of the world that can be mathematically expressed by fuzzy sets. Thus, we consider the following problem: the states of the world are fuzzy sets defined on the universal set on which the probability distribution is given. The two main ways how can be the probability of a fuzzy event expressed are proposed in the literature; first, as the expected degree of membership, and second, as a fuzzy probability. We will analyse how can be these two different ways applied to a decision matrix. Particularly, we will focus on how to compute and how to interpret in both cases the expected values of decision-maker's satisfactions by alternatives. The problem will be illustrated by an example.

■ TA-45

Tuesday, 8:30-10:00 - Graham Hills GH514 Lecture Theatre

Railway Timetabling

Stream: Optimization of Public Transport
Invited session
Chair: *Pieter Vansteenwegen*

1 - A Branch-and-Bound Approach for Robust Railway Timetabling
Gabor Maroti

We study robust train timetabling: we want to construct a timetable that leads to the least delays when operating under stochastic disturbances. Kroon et al. (2008) developed a stochastic programming model to improve the robustness of a reference timetable. While the model proved its value in practice, their solution method does not scale well: the solving time of real-life problems amounts to several hours or even days. In this research we propose an alternative solution method for the setting of Kroon et al. (2008). We design a branch-and-bound framework that is based on easy-to-compute lower bounds. We propose and compare various rules for node selection, for variable selection and for branching. We search for feasible solutions by solving linearised quadratic integer programs at each node of the branch-and-bound tree. Computations on real-life instances of Netherlands Railways show that we can vastly improve the robustness of the reference solution within a few minutes. The weak lower bounds lead to a considerable optimality gap. Our method is best described as a practice-driven heuristic approach.

2 - Passenger Robust Train Planning in Complex Station Areas
Sofie Burggraeve, Sofie Van Thielen, Pieter Vansteenwegen

Passengers prefer to arrive at their destination in the shortest possible time, even if not everything goes according to plan. The limited capacity of saturated station areas is one of the main reasons of delay propagation. We restrict ourselves to these busy and complex railway station areas. On the one hand, we developed a matheuristic that starts from an initial timetable and improves the total passenger travel time in practice (in case of frequently occurring small delays) up to 11% by taking passenger numbers and recurring delays into account. Scheduling highly occupied trains with more care restricts the probability that these trains get delayed and thus avoids their large impact on the total passenger travel time in practice in case of a delay. Furthermore, having a sound grasp of recurring delays also allows making a better schedule. Time buffers before the recurrent delayed train will be longer in practice than the planned time buffers and time buffers after the recurrent delayed train will be shorter during performance. On the other hand, we integrated two mixed integer programming models that construct a routing plan and a cyclic timetable from scratch which, respectively, optimally spread trains in space and time. The former model minimizes the maximum use of each switch and the latter maximizes the minimal buffer time in each switch. The performance of the resulting timetables of both approaches will be compared.

3 - Probabilistic Assessment of Process-Noise Covariance Matrix of Kalman Filter State Estimation for a Moving Train — Optimising the Rail Transport

Monish Sengupta, Daniel Woodland, Benjamin Heydecker

New train control systems rely mainly on Automatic Train Control (ATC) to dynamically control the speed and hence performance of a CBTC (Communication Based Train Control) train and within the ERTMS (European Rail Traffic Management System) system architectures. As we move towards advanced automatic railways we need greater control over the speed in order to achieve optimisation of public transport in terms of timetabling and maintenance. Reliable and accurate measurements of train location, speed and acceleration are hence vital. The application of a Kalman filter (KF) estimate can produce stunning results, while getting rid of all external reference points. However, the application of a KF estimate is largely dependent on the measurement and the process noise covariance matrices. While the application of this type of filter offers huge potential for benefit to the current technology, choice of the noise covariance is one of the many challenges in implementing this solution. This paper will discuss the application of KF alongside ATC and ERTMS technologies, including state estimates with various combinations of error covariance and noise covariance matrices. The assessment of the noise profiles will be shown through various simulation results. Practical considerations will be discussed with respect to experience already gained from KF application in other similar fields. The need for application of multiple KF on-board an ATC or ERTMS train will be shown as a consequence.

4 - Practical Evaluation of Railway Timetables

Pieter Vansteenwegen, Peter Sels, Thijs Dewilde, Dirk Cattrysse

Whenever a railway company updates or completely overhauls a timetable, it is highly important to evaluate the new timetable and compare it to the previous one. Today evaluation methods are typically restricted to simulation methods that do not report expected passenger time but focus on train delay propagation. Questions to be asked about the correctness and improvement of a timetable are: Are all minimum ride, dwell, transfer and headway times respected? Is total expected passenger time reduced? Is the average probability of missing transfers reduced? Is the timetable more robust against expected primary delays? Which regions, trains or train-pairs are causing expected passenger time or one of its components (ride, dwell, transfer knock-on time) to rise or diminish compared to the previous timetable. We provide a methodology and tools to answer all these questions. The output is presented graphically, so that the effects of changes in the timetable become more visually obvious. Since all components are measured and visualised in the same units, expected passenger time, the report supports the timetable constructor to make trade-offs. Our method is applied on the new and previous timetable of all passenger trains in Belgium. Our tool pinpoints where problems arise, where they are solved and clearly reports if the new timetable is better or not. It can then give the confidence needed to put a new timetable in practice.

■ TA-48

Tuesday, 8:30-10:00 - Graham Hilils GH510, Level 5

Facility Location for Electric Vehicles

Stream: Location
Contributed session
Chair: *Jörg Kalcsics*

1 - Integrating battery swapping stations location in a continuous network design problem with mixed gasoline and electric vehicles flows

Shengli Zhu, Jun Yang, Guangmin Wang

This paper presents a new continuous network design model to improve transportation network with mixed traffic flows (gasoline vehicles, GVs and electric vehicles, EVs) by expanding some links' capacities and locating the battery swapping stations (BSSs).The upper level is a model with objective function defined as the sum of total travel time on the network and the total investment cost of link capacity expansions and station locations. The lower level problem is formulated as a certain mixed traffic assignment model with driving range limit. For the proposed model, we design a hybrid meta-heuristic approach

named Quantum-Binary Particles Swarm Optimization (QBPSO) with modified Frank-Wolfe algorithm for solving this lower level problem. The experiments are illustrated on a test network with 18 links and 9 nodes to carry on the sensitivity analysis of the proportion of EVs, the driving range,the unit expansion cost and the value of time.

2 - A multi-objective approach to infrastructure planning in the early stages of EV introduction

Cristina Corchero, Andina Rosalya Brown, Oriol Serch, Miguel Cruz-Zambrano, F.-Javier Heredia

The aim of this study is to address the problem of locating fast charging stations for electric vehicles in the early stages of infrastructure implementation. Despite existence of successful trials and pilot projects, there are barriers preventing the successful development of a private EV market in its present state; investors are reluctant to invest in infrastructure due to the relatively small number of EV users, and conversely consumers are hesitant about purchasing EVs due high prices and a lack of charging infrastructure. It has been identified that introducing fast charging stations can aid this process, in particular by easing users' concerns about running out of charge before reaching their destination. This study approaches the problem from the perspective of a central planner wishing to install fast charging stations. A multi-objective approach is used to simultaneously consider two conflicting objectives in the optimisation problem: (1) to minimise the distance that potential consumers would need to deviate from their normal journeys in order to reach their nearest fast charging station and (2) to minimise the set up costs associated with the installation of the stations. A mathematical model is formulated and implemented to obtain results for the case study of Barcelona. The optimal solutions are found and used to depict the Pareto front, offering insight into the nature of the trade-offs between the objectives and aiding the decision making process.

3 - Heuristics for trip-based location of electric charging stations

Martin Koehler, Mario Ruthmair

Increasing environmental awareness and economic considerations of both private car drivers and logistics companies lead to the replacement of conventional vehicles with combustion engine by battery electric vehicles (BEVs). However, due to the highly restricted range of BEVs a dense network of charging stations is necessary to allow a comfortable daily usage. We consider the problem of selecting locations for charging stations for BEVs. Given is a street network with distances and travel times on the links, a set of potential locations for charging stations, a set of origin-destination (OD) pairs each one associated with a number of vehicles driving from O to D, and a maximal driving range. The aim is to find a subset of the potential locations which maximizes the coverage of OD traffic and which is limited by a given maximal number of charging stations. An OD pair is covered if it is possible to drive from O to D with a BEV respecting its maximal driving range and thus possibly visiting charging stations along the trip. Furthermore, a given maximal trip travel time related to the fastest path from O to D must not be exceeded. We present several greedy construction heuristics and improvement techniques to obtain high-quality solutions in reasonable time also for very large instances. Tests are performed on real-world instances arising in a current international research project.

4 - Preference-based equitable locations

Katarzyna Krupińska

We consider the problem of locating facilities on a directed graph. Facilities are allowed to be sit at the vertices of the graph. There is also defined a binary relation on the power set of the set of arcs, according to which preferred paths are determined. In an allocation phase, clients are assigned to facilities based on preferred paths, while in a location phase different location patterns are compared using another preference relation defined on the power set of the set of paths. We formalize the concept of an equitable location in this preference context by presenting conditions on preference relations under which a predefined solution may be obtained.

■ TA-49

Tuesday, 8:30-10:00 - Graham Hills GH511, Level 5

Evolutionary Algorithms

Stream: Metaheuristics
Invited session
Chair: *El-Ghazali Talbi*
Chair: *Leandro Parada*

1 - Scheduling technicians and tasks through the Biased Random Key Genetic Algorithm
Ricardo Damm, Debora Ronconi

This research analyses the field technician scheduling problem (FTSP) which service companies often face. The problem considers the assignment of a set of service tasks to a group of technicians. The tasks are in different locations within a city, with different time windows, priorities and processing times; technicians have different skills and working hours. The main objective is to maximize the number of priority tasks performed each day. We developed two customized Biased Random Key Genetic Algorithm (BRKGA) that uses random keys (real numbers between 0 and 1) and does not generate infeasible solutions. In this metaheuristic, a decoder transforms each chromosome into a feasible solution of the optimization problem. In the decoder of the first BRKGA, a randomly technician is select for each task; for the second, the decoder choose a technician based on a strategy that explores specific characteristics of the problem (task priorities, geographic clusters, technician skills and travel times). Quality and diversity were combined to select the elite solutions for improving the performance of the BRKGA. A total of 1040 instances were generated in the numerical experiments, with up to 166 technicians and 999 tasks. In a comparative study with optimal solutions obtained for small-sized problems, the best BRKGA reached 98% of the optimal values; for medium- and large-sized problems, the BRKGA provided solutions that are on average 3.8% below the upper bounds.

2 - Biased random-key genetic algorithms for divisible load scheduling
Celso Ribeiro, Julliany Brandão, Thiago F. Noronha, Mauricio Resende

A "divisible load" is an amount W of computational work that can be arbitrarily divided into chunks and distributed among a set P of worker processors to be processed in parallel. Divisible load applications occur in many fields of science and engineering. They can be parallelized in a master-worker fashion, but they pose several scheduling challenges. The Divisible Load Scheduling Problem consists in (a) selecting a subset A of active workers, (b) defining the order in which the chunks will be transmitted to each of them, and (c) deciding the amount of load that will be transmitted to each worker in subset A, so as to minimize the makespan, i.e., the total elapsed time since the master began to send data to the first worker, until the last worker stops its computations. In this work, we propose biased random-key genetic algorithms for solving both the single- and multi-round versions of the divisible load scheduling problem. Computational results show that the proposed algorithms outperform the best heuristics in the literature.

3 - A hybrid genetic algorithm for the assembly line balancing problem with incompatible tasks
Mariona Vila Bonilla, Jordi Pereira

Assembly line balancing problems appear in industrial contexts when each production task needs to be assigned to one of the stations on the assembly line, while maximizing a measure of the efficiency of the line. We propose a new hybrid metaheuristic to solve a version of the problem in which some sets of tasks cannot be assigned in the same station, because they are incompatible. Our proposal uses a genetic algorithm to explore a space of instances in which more incompatibilities between tasks have been added to the original instance. The fitness of each individual is then measured by solving the modified problem using a dynamic program. Additionally, the dynamic program makes use of several new lower bounds and reduction rules to reduce the number of states, and the genetic algorithm is parallelised to use the multi-core structure of current commodity computers. The results of the computational experiments show that the implemented algorithm outperforms any previous procedure found in the literature and improves upon the best-known solution for eight of the benchmark instances for the SALBP-2 used in the literature for comparison purposes.

4 - Wind farm layout optimization using a genetic algorithm
Leandro Parada, Rodrigo Castro Gonzalez, Lorena Pradenas

In the present study an optimization model by means of a genetic algorithm for the location of turbines in a wind farm is proposed. This will be achieved by minimizing an objective function that represents the costs per unit of energy generated, given a function of wind distribution. In addition, an analytical model that allows modeling the wake generated by these turbines is used. In order to estimate the power generated by a turbine operating in the wake of one or more turbines, the model proposed by Jensen & Jensen (1983), with the global conservation of the momentum in the wake zone behind the turbine is considered. This is based on the assumption that the wake has a turbulent flow and the contribution of tip vortices is disregarded. In addition, the minimization of cost per unit of energy generated is taken into account, also considering the wake effect. The proposed method is assessed with five different scenarios. It is solved in a MATLAB platform and optimtool and in a computer with a 2.7 GHz. Pentium Dual Core processor and 4 GB Ram memory. The method provides the layouts of the farms with an appropriate distribution, according to the physical space. It was concluded that the proposed method is an effective tools for solving the problem. However, it is necessary to incorporate the randomness of wind directions, as well as a distribution function of the wind speed based on actual instances.

■ TA-50
Tuesday, 8:30-10:00 - Graham Hills GH512, Level 5

Horizontal Transportation and Hinterland Connections

Stream: Container Terminals
Invited session
Chair: *Claudia Caballini*

1 - Modeling Man-Guided Vehicle Trips in a Container Terminal via Simulation
Rina Mary Mazza, Pasquale Legato

A micro-simulation model aimed at representing the dynamics of container transportation operations back and forth between the quay and yard areas in a pure transshipment container terminal is presented. A fleet of man-guided straddle carriers (SCs) is employed for container transfer during which the path between any couple of origin and destination points are determined by real-time driver decisions. The simulator embodies a multi-step decision process that mirrors the en-route behavior implemented by the SC drivers as a response to the information they receive during their trip. An event-based view, under stochastic conditions, is adopted to reproduce the point-to-point transfer process for each SC along the internal reticular paths within the Manhattan-like layout of the storage blocks in the yard. The problem tackled herein consists in estimating the number of SCs to be assigned to each quay crane involved in discharge/loading operations, while accounting for vehicle traffic, congestion and disruptions encountered by the SCs. Statistical figures are returned for estimating container transfer times and transfer productivity as the congestion increases along both horizontal and vertical corridors of the yard, as well as at intersection points. Measuring these transfer times may be useful to support further quantitative evaluations within the overall discharge-transfer-loading process. Numerical simulation experiments based on real-life data are presented.

2 - A Recommender System for Assigning Work Schedules to Straddle Carrier's Drivers
Khaled Mili

One of the success factors of a terminal is related to the time in port for the retrieval and transport of containers. Straddle carriers (SCs) are the pivotal axis around which the terminal transportation system evolves and the success or failure of that process is an indicator of the reliability of the container terminal. Over the last years, the deficiency of efficient control and coordination mechanisms in practice produced a relaxation of transportation principles. The valorization of the academic environment represents nowadays one of the most important research challenges. In this paper, we present a collaborative filtering recommender system able to manage the work schedule's assignment to straddle carrier's drivers in a container terminal and provide preliminary results on customer's satisfaction.

3 - The Impact of Foldable Containers for Simultaneous Truck Routing of Loaded and Empty Containers in Hinterland Transport of Seaports
Koichi Shintani, Etsuko Nishimura, Rob Konings, Akio Imai

This study analyzes the impact of foldable containers on cost savings in transporting loaded and empty containers by trucks in the hinterland transport of seaports. The problem is formulated as a kind of the vehicle routing problem with pickup and delivery. A simulated annealing

algorithm-based metaheuristic is developed for solving the problem. Numerical experiments are performed with realistic scenarios that often arise due to imbalanced inbound and outbound flows in the hinterland. The study finds that foldable containers can significantly reduce the number of used trucks, trip length of truck haulage and the number of handlings compared to standard containers.

4 - Addressing Congestion Issues in Container Terminals with a Non-mandatory Truck Appointment System

Claudia Caballini, Simona Sacone, Daniela Ambrosino

The increasing volume of goods affecting seaports generates increasing number of trucks approaching container terminals for delivering and withdrawing containers. If not properly managed, truck arrivals may determine critical congestion issues, affecting both truck service times, terminal productivity and mobility related to urban areas. So, researchers and practitioners are paying increasing attention to this matter. The aim of the present paper is to model and analyze the use and benefits of a non-mandatory Truck Appointment System (TAS) in a container terminal with the aim of minimizing congestion both outside the gate area and inside the terminal. Both strategic issues, such as the sizing of the TAS in terms of truck lanes number and related productivity, and operative questions, including the number of booked lanes to be activated or the number of trucks that are recommended to book in each time horizon, are addressed in this work. A linear mathematical programming problem based on a flow network has been developed and implemented in C# programming language and solved by using C-plex solver. Real data related to container terminals located in Mediterranean Basin have been used to validate the model. The proposed approach has been successfully tested on different scenarios, varying terminal congestion levels, number of gate lanes, number of trucks arrivals and trucks tasks to be executed. Results and comparisons among scenarios will be presented at the conference.

■ TA-51

Tuesday, 8:30-10:00 - Graham Hills GH542, Level 5

MAI: Efficient modelling and solving of non-linear optimisation problems

Stream: Making An Impact 1 (MAI 1)
Invited session
Chair: *Susanne Heipcke*

1 - Efficient modelling and solving of non-linear optimisation problems

Zsolt Csizmadia, Susanne Heipcke

In this workshop for OR practitioners we give an introduction to formulating and solving nonlinear optimisation problems.

We begin with presenting typical examples and types of nonlinear problems and the categories of available nonlinear solvers.

The second part discusses techniques and modelling approaches focusing on how solvers handle each problem, including - easy and hard to solve formulations - cascading in blending models - convergence for highly degenerate models - large recourse-type formulae - MINLP with negative GAP - purely discrete nonlinear problems

This tutorial is aimed at OR practitioners who have some experience with LP/MIP, but no or little experience with non-linear programming (NLP) but who would like to learn about NLP / possibly wish to extend an existing model with some nonlinear features.

Bring your laptop and you can try the software.

■ TA-52

Tuesday, 8:30-10:00 - Graham Hills GH554, Level 5

Risk Modelling and Financial Constraints

Stream: Financial Mathematics and OR
Invited session
Chair: *Jonathan Crook*
Chair: *Rita D'Ecclesia*

1 - A Comparison of Methods of Estimating Credit Card Exposure at Default and a New Mixture Model

Jonathan Crook, Mindy Leow

Using a large portfolio of historical observations on defaulted loans, we estimate Exposure at Default at the level of the obligor by estimating the outstanding balance of an account, not only at the time of default, but at any time over the entire loan period. We assume that the outstanding balance on a credit card account at any time during the loan is a function of the spending and repayment amounts by the borrower and is also subject to the credit limit imposed by the card issuer. The predicted value is modelled as a weighted average of the estimated balance and limit, with weights depending on how likely the borrower is to have a balance greater than the limit and are derived from a repeated events survival model. We compare the performance of this new model with traditional methods in the literature such as the LEQ, CCF and EADF methods and make suggestions as to when each is more appropriate.

2 - Tracking error means square via quantile regression. A dispersion measure for the index tracking problem.

Marco Cassader, Rosella Giacometti

This paper analyzes the impact of a new measure of dispersion in the index tracking problem. This type of problem consists to replicate the performance of a given index or benchmark with its components. Portfolio managers usually address with the index tracking problem minimizing the difference between portfolio and benchmark returns. This different is defined as the tracking error and a variety of dispersion measures of tracking error has been proposed in the financial literature. In this work, we introduce the tracking error mean square via quantile regression based on the relation of how the quantiles of the dependent variable vary with the independent one. For this reason, considering a set of quantiles we solve the index tracking problem in a static or dynamic framework. In particular, we analyze the in sample and out of sample results and we propose a dynamic approach based on the selection of the best quantile. Empirical results dictate the dominance in a reward-risk sense of this new dispersion measure with respect to the common tracking error mean square, tracking error volatility and tracking error mean absolute deviation. Finally, we investigate the impact of the new approach in different index tracking portfolio optimization problems.

3 - Modelling Dependence in Exchange Rates: Application of GARCH-Copula Model

Ales Kresta

Time series modelling and subsequent risk estimation is a difficult and important activity of any financial institution due to the volatility clustering and heavy-tailed distribution of returns. Both these characteristics have a great influence on risk estimation. Also, the dependence plays and important role (the extreme gains/losses are usually more correlated than the gains/losses close to the mean). In the paper we focus on foreign exchange rates, for which we apply GARCH model. Further, we focus on the dependence between two foreign exchange rates and study GARCH-copula models. The copula functions are the tool which allows us to model the dependence among individual risk drivers (exchange rates). On the other hand, GARCH model allows to depict the volatility clustering. Concretely, GARCH model with Student distribution of innovations and various copula functions are assumed in the paper. These joined models are backtested on chosen dataset and the quantities of VaR violations (i.e., their quantity and distribution in time) are statistically tested by Kupiec and Christoffersen tests.

■ TA-53

Tuesday, 8:30-10:00 - Graham Hills GH614, Level 6

Dynamic Game Theory & Opinion Dynamics and Influence Systems

Stream: Dynamical Systems and Mathematical Modelling in OR
Invited session
Chair: *Ryusuke Hohzaki*
Chair: *Jörg Rambau*

1 - On a Large Population Partnership Formation Game with Continuous Time

David Ramsey

This paper presents a model of partnership formation in which there are two classes of player (called for convenience male and female). There is a continuum of players and n types of male and female. Each player begins searching at time zero and the mating season is of finite length. Each player searches until he/she finds a mutually acceptable prospective partner and then this pair both leave the pool of searchers. Hence, as the season progresses, the proportion of players still searching for a partner decreases and the distribution of types changes appropriately. The rate at which prospective partners are found is a non-decreasing function of the proportion of players still searching. The value of pairing with a partner is equal to the value of that partner discounted according the time at which a partner is found. At a Nash equilibrium, each searcher accepts a prospective partner if and only if the value obtained from such a partnership (ignoring previously incurred discounts) is greater or equal to the expected value obtained from further search. Some general results are given. In addition, we derive the form of the equilibrium when there are two types and present two examples known as the singles bar model and the random mixing model, respectively.

2 - A search allocation game with the private information about target's initial condition

Taihei Matsuo, Ryusuke Hohzaki

This paper deals with a search allocation game (SAG), in which a searcher tries to detect a target by distributing its search resources and the target moves to avoid the detection by the searcher. Since the initial condition of the target gives great impacts on the result of search operations, in this paper we discuss a SAG with the target's initial condition, which consists of its initial position and initial moving energy, as target's private information. We propose mathematical programming methods to solve the SAG, and numerically show the characteristics of optimal players' strategies and the importance of private information.

3 - Recent progress on the Hegselmann-Krause bounded confidence model

Peter Hegarty

This famous model from 2002 remains one of the most popular and actively studied models of opinion dynamics, having a natural and simple formulation which nevertheless leads to beautifully complex dynamics. This sequence of lectures will present a series of recent, mathematically rigorous results, plus a description of an intriguing novel variation on the model in which strategic agents try to influence the dynamics. In the classical version of the model, agents' opinions are represented by real numbers, time is discrete and at each step all agents simultaneously update their opinion to the average of those currently lying within distance one of their own. A fundamental result is that any initial configuration of opinions will freeze in finite time, bounded by a universal polynomial function of the number n of agents. The current best upper bound is cubic in n. There has been significant recent progress concerning lower bounds, which will be the main focus of this talk. Firstly, it was known for some time that n equally spaced opinions require Omega(n) steps to freeze. Recent work pins down precisely the evolution of such a configuration, with intriguing problems remaining as the inter-agent spacing tends to zero. Secondly, we discovered an example of a configuration which takes quadratic time in n to freeze, the first non-trivial tightening of the gap between upper and lower bounds.

4 - Optimal Opinion Control and the Campaign Problem

Jörg Rambau, Rainer Hegselmann, Stefan König, Sascha Kurz, Christoph Niemann

Picture yourself in a committee of experts that has been asked to assess a certain issue. The committee consists of eleven members with individual opinions. Ten meetings are available to exchange opinions. By which strategy can you convince as many members as possible of your position? In this talk we analyze this campaign problem mathematically and computationally. We use a simplified model of interaction in order to isolate basic structural properties of rational strategic behaviour. Our formalization is based on the famous bounded-confidence model by Hegselmann and Krause. In this model, opinions are numbers in the unit interval. The dynamics of opinions is given by averaging with those opinions that are not too far apart. The new element in our analysis is the introduction of a control: In each meeting, we can hold a carefully chosen opinion in order to pull as many opinions as possible closer to our own. This can be interpreted as an instance of diplomacy. It turns out that opinion controls that convince the maximum number of committee members are hidden. However, they can be

narrowed down by a combinatorial heuristics and involved mixed integer linear programming techniques (MILP). With this, we can solve the original toy problem. However, for seven, eight, and nine meetings, the maximal numbers of convincible members remain open. Remark: The corresponding MILPs are part of MIPLIB 2010; some of them have been classified as "challenge".

■ TA-54

Tuesday, 8:30-10:00 - Graham Hills GH617, Level 6

System Dynamics Session 1

Stream: System Dynamics Modeling and Simulation
Invited session
Chair: *Andreas Größler*
Chair: *Evgenia Ushakova*

1 - Performance Effects of Volatility in Strategic Resources

Andreas Größler

Inspired by work in the natural sciences, this paper argues that ultimately only rigid systems (one might say "dead' systems) are not characterised by some form of volatility, being it random fluctuations or more orderly oscillations. Thus, volatility seems to be a necessary condition for the viability of living systems. This idea is transferred to business organisations and it is argued that variability (that managers try to fight in their quest for stability) can actually be instrumental for creating sustainable success. More concretely, the modification of organisational resources to adjust to varying environmental demands is investigated. By way of a low-order balancing feedback process characterised by perceptive and material delays, these resources (which, for instance, might be personnel, machinery, or firm-specific knowledge) are adapted to provide a fit with external requirements. The simulation model used for the analyses is derived from widely-accepted published work in the field of system dynamics and informed by empirical evidence. Performance measures defined include costs for resource adaptation and costs for resource misfit with environmental demands, from which an overall performance score is constructed.

2 - Are Regulators Doing the Wrong Thing?

Dennis Sherwood

Many recipients of a service — such as financial advice or elderly care — do not have the requisite knowledge to determine whether or not the service they are receiving is of an appropriate quality. Furthermore, many such people are in a weak position to complain. As a consequence, many people can be receiving sub-standard service, which the supplier continues to deliver with impunity. Why does this market failure occur? Are regulators doing the wrong thing? These questions are of great social importance, for we all intrinsically trust our service provider: that elderly person in the care home naturally assumes that the dose of medicine just received is correct. There is, however, much evidence that mistakes and errors are made - mistakes and errors that come to light only after the damage has been done, either because a complaint is made, or because an inquiry is initiated, perhaps by the government. Why did these errors occur in the first place, and what has the regulator been doing - if anything - to prevent them? These service failures do not arise in a single sector, or in the area of a single regulator, or at a specific time. They are truly systemic, and so this paper uses systems thinking and causal loop diagram to identify, precisely, what the systemic flaw is, and also to identify a solution.

3 - How Risky is Climate Change? Environmental Credit Risk Perception within a Bank

Sarah Megan Boyar

The advent of free trade and the globalizing of markets in the 1980s coincided with an increase in 'surprise' impairments and premature write-downs in accounting. The term stranded assets emerged during this era as a metaphor for a certain type of impairment, describing when an asset's book value irreversibly becomes less than its market value due to changes in the regulatory environment. Originally the stranded assets metaphor was leveraged by major energy companies to win compensation when their business model was crippled by government-led deregulation and the transition to competition. In a recent twist, however, the phrase stranded assets has entered a more general public discourse due to the realization that if nations worldwide honour their carbon emissions commitments, then fossil fuel producers have far more production capacity on their books than will ever be demanded in the markets. My doctoral research examines how bank

lenders perceive the risk of 'stranded fossil fuel assets' in a context of global climate change. Bank lenders have increasingly included environmental considerations in their credit risk assessments. Many social theorists offer that uncertainties become risks when they enter formal management systems. In a case study with a global financial institution, my research draw upon techniques derived from System Dynamics to offer an account of the processes through which perception of environmental credit risk enters bank management systems.

■ TA-55

Tuesday, 8:30-10:00 - Graham Hills GH626, Level 6

Numerical and Simulation Methods in Finance 1

Stream: Numerical and Simulation Methods in Finance
Invited session
Chair: *Aysegul Iscanoglu Cekic*
Chair: *Gerhard-Wilhelm Weber*
Chair: *Erdem Kilic*

1 - Measuring the Risk of a Nonlinear Portfolio with Fat-Tailed Risk Factors through Probability Conserving Transformation
Paresh Date, *Roberto Bustreo*

In this work, we present a new heuristic for fast approximation of VaR (Value-at-Risk) and CVaR (conditional Value-at-Risk) for financial portfolios where the net worth of portfolio is a nonlinear function of possibly non-Gaussian risk factors. In this method, the possibly fat tailed marginal distributions of risk factors are mapped through a probability conserving transformation on to Gaussian marginal distributions. A new sample covariance matrix of the transformed variables is then computed and it redefines the dependence among the transformed risk factors. Delta-Gamma coefficients obtained under Normal conditions are multiplied by coefficients that take into account the non-normal nature of the original risk factors. Given the transformed values of Delta, Gamma and the covariance matrix, VaR of the portfolio is computed using a Fourier inversion integral, similar to the Delta-Gamma method with Normal risk factors, i.e., the quadratic VaR method. The computational load of the new method to compute VaR is comparable with the Delta-Gamma Normal method, i.e., is much lower in general than a full Monte Carlo evaluation. However, unlike the Delta-Gamma Normal method, the new method preserves the fat-tailed nature of the risk factors. A wide variety of marginal distributions can be used to model the risk factors, including non-parametric marginals. We demonstrate the utility of the new method with comprehensive numerical experiments on simulated as well as real financial data.

2 - A Study of Banking Stocks in India to Develop a Model for Prudent Investment
Rama Krishnan, *Badri Toppur*

Investments in stock markets have always been volatile, uncertain, complex and ambiguous. Can we overcome these hurdles by adopting a suitable research in a particular industry with the probable risk and uncertainty embedded? This inquisitiveness has triggered this analysis, and the banking sector has been chosen for the study. The financial results published by the various banks up to the year ending December 2014 have been taken up for our scrutiny. The forces of demand and supply have direct effect on the stock prices. On the other hand, the number of other firms, the particular industry, and country influences the share prices. One of the major and important determinants of stock prices is volume traded in stock exchange market. Inflation can also be a great cause for changes in share price. The interest rate mechanism and the statutory rates to be maintained by commercial banks as per the norms suggested by Central Bank periodically also impact the price volatility, particularly among the banking stock. Provision for Non-Performing Assets and the asset quality of the organized sector of Financial Markets has a major impact on the stock valuation. An attempt has been made to identify the variables which are significant from the investor's point of view and to suggest a rational methodology for investing.

3 - Simulation Model for Two-Tier Pension Policy
Tadashi Uratani

Growing aging population with the low fertility has brought a severe picture to maintain the pension scheme in near future. The financial viability of public pension requires the reserve should be positive to pay the benefit in the demographic and economical environment change subject to maintain the certain level of the income replacement ratio. The two-tier public pension has a scheme which consists of constant and wage-proportional benefit and premium. The policy depends only four variables of premium and benefit for two schemes but the difficulty exits in the long time decision for life span and the economic equality of various cohorts in the uncertain future environment. Assuming that the price of the market asset and the average wage follow stochastic processes, we consider the net present value of pension for the cohort. To guarantee the viability of pension, we obtain conditions by the martingale method of Uratani. The policy constraints is considered to minimize the net present values of the two-tier pension for the cohort. Finally the annual balance of two-tier pension is simulated under the policy constraints in order to achieve the objective of pension. The result is compared with Japanese government actuarial valuation.

4 - A Model Selection Method for Option Pricing
Berk Orbay, *Refik Gullu*, *Wolfgang Hörmann*

Empirical evidence on comparison of option pricing models shows that there is no consensus on a single dominating model for all contract parameters and over different time periods. We propose a clustering method to find the relevant regions of contract parameters for model selection. Then, we use a decision rule to select the most suitable model over these regions. Finally, we provide out-of-sample testing results using different assets and option pricing methods over different time periods.

■ TA-60

Tuesday, 8:30-10:00 - Graham Hills GH813, Level 8

Efficient Search Mechanisms for Routing Problems

Stream: Routing I - Models and Methods
Invited session
Chair: *Wout Dullaert*

1 - Effective speed-up strategies for tabu search heuristics
David Lai, *Wout Dullaert*

Tabu search metaheuristics have been developed for decades, making them one of the most widely applied metaheuristic frameworks. Although a standard tabu search framework can offer interesting performance, the effectiveness of a tabu search metaheuristic can be strongly improved by specific implementation features and speed-up strategies that are often overlooked in standard implementations. This presentation discusses a number of speed-up strategies and provides computational results on their effectiveness.

2 - An Efficient Implementation of a Static Move Descriptor-based Local Search Heuristic
Wout Dullaert, *Onne Beek*, *Birger Raa*, *Daniele Vigo*

In this presentation, we analyze the concept of Static Move Descriptors to speed up Local Search algorithms. We present several modifications for the original concept developed by Zachariadis and Kiranoudis (2010) and formulate an efficient implementation capable of significantly improving the performance of Local Search algorithms. This framework can easily be embedded in metaheuristics that use Local Search and is compatible with any neighborhood sparsification strategy.

3 - Splitting Giant Tours using Lagrangian Relaxation
Said Salhi, *Mouaouia Cherif Bouzid*, *Hacene Ait Haddadene*

In this talk, we present a Lagrangian relaxation method (LR) as an alternative way for the partitioning of a giant tour. We first recall the principle of route first cluster second approaches in routing problems. The standard partitioning ILP formulation is then provided and tested. Though there are polynomial algorithms for splitting giant tours for

certain classes of routing problems (CVRP, VRPTW, etc), we aim to produce a general methodology for splitting giant tours using Lagrangian relaxation. In this study, we build an LR approach to initiate such a task. An efficient repair algorithm followed by a local search are embedded into the process. This approach is then embedded into a general variable neighbourhood search heuristic (GVNS) to make up a matheuristic. Our initial implementation is initially tested on the classical VRP instances to illustrate the efficiency of such an approach.

4 - Adaptive Large Neighborhood Search using the Graphics Processing Unit

Lukas Bach, Geir Hasle, Christian Schulz

We investigate the efficiency of Adaptive Large Neighborhood Search (ALNS) on the Graphics Processing Unit (GPU). We do this by implementing an ALNS algorithm for the Distance-constrained Capacitated Vehicle Routing Problem (DCVRP), which we benchmark towards a state of the art sequential implementation by Pisinger and Ropke [1].

In recent years the computational capacity of the GPU in ordinary desktop computers has increased significantly compared to the CPU. In a survey, Schulz et al. [2] find that most routing related GPU implementations use swarm intelligence, evolutionary, or local search based algorithms. To the best of our knowledge, there are no papers on ALNS implementations on a GPU.

A part of ALNS is a neighborhood search where destroy operators remove parts of an existing solution and repair operators reinsert them. Compared to the CPU based implementation, it is necessary to adapt some of the operators to achieve a good utilization of the GPU. We perform tests on well-known DCVRP instances. Our experiments show promising results.

References:

[1] David Pisinger, and Stefan Ropke, A general heuristic for vehicle routing problems, Computers & Operations Research 34, 2403-2435 (2007)

[2] Christian Schulz, Geir Hasle, André R. Brodtkorb, and Trond R. Hagen, GPU computing in discrete optimization. Part II: Survey focused on routing problems, EURO Journal on Transportation and Logistics 2, 159-186 (2013)

■ TA-61

Tuesday, 8:30-10:00 - Graham Hills GH816, Level 8

Green Routing and Logistics - II

Stream: Routing II - Emerging Applications
Invited session
Chair: *Richard Eglese*

1 - Combined Ship Speed and Route Optimization: Models and Tradeoffs

Harilaos N. Psaraftis

We review models that combine ship speed and routing decisions for a spectrum of ship routing scenarios and for several variants that concern the objective function to be optimized. Routing scenarios include fixed route (only speed is optimized), as well as pickup or delivery, and pickup and delivery. It is seen that fundamental considerations for combined speed and route optimization include (a) the fuel price, (b) the state of the market (freight rate), (c) the inventory cost of the cargo, and (d) the functional dependency of fuel consumption on payload. Depending on various parameters, solutions for optimal environmental performance may or may not be the same as those for optimal economic performance. In addition, policies that may seem at first glance optimal from an environmental viewpoint (for instance, sailing the minimum distance route at minimum speed) may actually be suboptimal. Various examples illustrate the properties of the optimal solution and the various tradeoffs that are involved.

2 - Constrained Vehicle Routing and speed optimization Problem (CVRsoP) for Electric Vehicles

Maud Bay, Sabine Limbourg, Vítor Lemos

One of the goals of the EU is to achieve essentially CO_2-free city logistics in major urban centers by developing and deploying new and sustainable fuels and propulsion systems. To meet European air quality standards, authorities of some major European cities have already

introduced Low Emissions Zones where access to urban areas is limited to freight vehicles that satisfy certain emissions limits. This paper, therefore, copes with zero-emission last mile delivery.

Our model has its roots in the Pollution Routing Problem and in the Green Vehicle Routing Problem. In addition to acknowledging the previous view, we define the Constrained Vehicle Routing and speed optimization Problem (CVRsoP) for routing optimization of deliveries with electric vehicles having limited battery capacity. In this case not only the loads carried but also the driving speeds have a great impact on the driving range and the optimal routes for deliveries. The mathematical formulation leads to a non-linear model with mixed variables (discrete and continuous). We decompose the problem in two parts: a delivery routing problem, which is a classical CVRP, and a speed optimization problem.

Our approach is applied to extended benchmark instances and to realistic instances, using technical data of real electric trucks. Results provide optimal routings. Moreover insights can be driven on the preferable locations of depots in non-smooth geographic areas.

3 - The Maximin-Maxisum HAZMAT Routing Problem

Andres Bronfman, Vladimir Marianov, German Paredes-Belmar, Armin Lüer-Villagra

We address the hazardous material routing problem in an urban area, in which vulnerable centres (facilities difficult to evacuate in a short time) have to be protected. We maximize two objective functions: the distance between the route and its closest vulnerable centre (maximin objective) and the sum of the distances between the route and all vulnerable centres within a hazard radius of it (maxisum objective). Both functions are weighted by the number of people considered in them. Although the first objective alone defines a polynomially solvable problem, the addition of the second objective makes the problem NP-complete, at least. We analyze the trade-offs of using these objective functions and analyze the effects of different weights. As the maximin objective becomes more important, the vulnerable centre that is closest to the route obtains more protection, but the average risk or hazard increases. A heavier weight on the maxisum objective, on the other hand, exposes the closest centre to more danger. We apply our methodology to the city of Santiago, Chile. The results show the benefits of our approach.

4 - An Exact Algorithm for the Green Vehicle Routing Problem

Enrico Bartolini, Juho Andelmin

We present an exact algorithm for solving the Green Vehicle Routing Problem (Erdogan and Miller-Hooks, 2012). The problem is to service a set of customers by using a fleet of alternative fuel vehicles with limited driving range subject to maximum route duration constraints. Vehicles can stop at refuelling stations en-route to fully restore their driving range at the expense of a fixed stop time. We model the problem by using a set partitioning formulation strengthened by valid inequalities. Its LP relaxation is solved by cut-and-column generation to compute a lower bound corresponding to the cost of an optimal dual solution. The pricing problem is modelled as an elementary shortest path problem with resource constraints defined over a multigraph, and it is solved by dynamic programming. The exact algorithm uses the dual solution to attempt enumerating a subset of routes which contain an optimal solution. We report computational results on benchmark instances and newly generated ones.

■ TA-62

Tuesday, 8:30-10:00 - Livingstone LT203, Level 2

Operations Research 5

Stream: Operations Research, other
Contributed session
Chair: *Chiara D'Alpaos*

1 - An AHP Model to Assess Property Investments Riskiness

Chiara D'Alpaos, Rubina Canesi

When the future is uncertain and investments are durable and illiquid the decision to invest at a certain time contingent to new information to come as well as the correct assessment of risks are a key issues especially in times of global financial crisis. In order to make the decision, investors need to measure risks and identify the relationship between risks borne and risk premiums demanded. Real estate development is de facto a dynamic multiphase process and all the phases of the housing industry are interrelated, and each stage involves various risks, differently allocated between landowners, land developers, and homebuilders. Aim of the paper is to provide an overall risk scoring model that allows to rank real estate investments based on their riskiness. We focus on economic risks and mainly address Market Risks and Real Estate Operating Risks. We implement therefore an AHP model to rank the overall riskiness of property investments (i.e. urban development projects). The AHP risk assessment model here proposed may have interesting effects in terms of risk management strategies. Each investment criteria can be in fact related to a specific risk measure, therefore the investor can revise or adapt decisions in order to reduce a specific risk component to acceptable reliance level (in accordance to his risk attitude) and in turn increase the investment's economic performance.

2 - An Optimal Algorithm for Finding (r, Q) Policy in a Price-dependent Order Quantity Inventory System with Soft Budget Constraint
Hamid Mirmohammadi, Shahrzad Tamjidzad

This paper is concerned with the single-item continuous review inventory system in which demand is stochastic and discrete. The budget consumed for purchasing the ordered items is not restricted but it incurs extra cost when exceeding specific value. The unit purchasing price depends on the quantity ordered under the all-units discounts cost structure. In many actual systems, the budget as a resource which is occupied by the purchased items is limited and the system is able to confront the resource shortage by charging more costs. Thus, considering the resource shortage costs as a part of system costs, especially when the amount of resource occupied by the purchased item is influenced by quantity discounts, is well motivated by practical concerns. In this paper, an optimization problem is formulated for finding the optimal (r, Q) policy, when the system is influenced by the budget limitation and a discount pricing simultaneously. Properties of the cost function are investigated and then an algorithm based on a one-dimensional search procedure is proposed for finding an optimal (r, Q) policy which minimizes the expected system costs.

■ TA-66
Tuesday, 8:30-10:00 - Livingstone LT209, Level 2

Polyhedral aspects

Stream: Optimization
Invited session
Chair: *Andrei Nikolaev*

1 - Some properties of the Boolean quadric polytope extension
Andrei Nikolaev

Following the seminal work of Padberg on Boolean quadric polytope BQP and its LP relaxation BQP_LP, we consider a natural extension: SATP and SATP_LP polytopes, with BQP_LP being the face of SATP_LP (and BQP the face of SATP). Various special instances of 3-SAT problem like NAE-3-SAT, 1-in-3-SAT, weighted MAX-3-SAT, and others can be solved by integer programming on SATP_LP. We describe all integral vertices of SATP_LP. Like BQP_LP, polytope SATP_LP has the Trubin-property being quasi-integral (1-skeleton of SATP is a subset of 1-skeleton of SATP_LP). However, unlike BQP, not all vertices of SATP are pairwise adjacent, the diameter of SATP equals 2, and the clique number of 1-skeleton is superpolynomial in dimension. It is known that the fractional vertices of BQP_LP are half-integral (0, 1 or 1/2 valued). We show that the denominators of SATP_LP fractional vertices can take any integral value, with the largest denominator growing exponentially. Finally, we use the properties of vertices to describe the polynomially solvable cases of integer programming and integer recognition problems on SATP_LP.

2 - Valid Inequalities for the Workforce Planning Problem
Prasenjit Mandal, Ishwar Murthy

Workforce planning has long been identified as an opportunity for research by both academicians and industry practitioners. Professional service firms (PSF), like management consulting firms offers a wide range of services over several application areas to their clients. Projects are the primary medium through which a PSF aims to deliver high-quality services. It turns out that obtaining a minimum cost plan to assign resources with diverse skills and delivery roles to several client projects is particularly challenging. Poor workforce management, including inappropriate and inefficient allocation mechanism to projects and improper resource utilization, can adversely impact the financial outcome of a PSF. To address the above problem, a mathematical programming model is considered. Given a set of projects, a set of resources and a time horizon, the workforce planning problem (WPP) seeks to find the minimum-cost way of allocating resources to projects over time horizon so that the project demands in terms of man-hour are satisfied. The problem is mathematically formulated as an integer linear program (ILP) which is computationally hard to solve. The main proposed contribution of this paper is to identify several classes of strong valid inequalities that are specific to the ILP formulation. These families of valid inequalities tighten the LPR and therefore speed up the solution procedure. Our present work is one of the first attempts to find the valid inequalities for the WPP.

3 - The skeleton of polytopes of connected graphs with cycles
Liliana Costa, Carlos Nascimento, Nair Abreu

Nair Abreu, Liliana Costa and Carlos Nascimento

Abstract Let T be a tree with n vertices. The corresponding acyclic Birkhoff polytope, n(T), is the set of doubly stochastic matrices whose support is T. Given a graph G, the matching polytope, M(G), is the polytope whose vertices correspond to the matchings of G and the edges are the faces of dimension 1 in the polytope. In [1], it is shown that n(T) and M(T) are affinely isomorphic. The skeleton of M(T) is the graph denoted by G(M(T)), whose vertices are the vertices of M(T) and two matchings are adjacent if and only if their symmetric difference is a path. Some properties of this graph have been studied and their minimum degree and diameter were determined, [2] and [1]. In this paper, we investigate similar properties to the skeleton of polytopes of connected graphs, distinct of trees, that belong to specific classes. These classes are defined by graphs with either a path or a star as one of their spanning trees.

[1] L. Costa, C. M. da Fonseca, E. A. Martins, The diameter of the acyclic Birkhoff polytope, Linear Algebra Appl. 428, 1524-1537, 2008. [2] N. Abreu, L. Costa, G. Dahl, E. Martins, The skeleton of acyclic Birkhoff polytopes, Linear Algebra Appl. 457, 29-48, 2014.

■ TA-67
Tuesday, 8:30-10:00 - Livingstone LT210, Level 2

Industrial Applications of Combinatorial Optimization

Stream: Combinatorial Optimization
Invited session
Chair: *José Fernando Oliveira*
Chair: *Ana Raquel Xambre*

1 - Minimising Total Tardiness for a Single Machine Scheduling Problem with Family Setups and Resource Constraints
Asvin Goel, Oliver Herr

This paper considers a single machine scheduling problem in which each job to be scheduled belongs to a family and setups are required between jobs belonging to different families. Each job requires a certain amount of resource that is supplied through upstream processes. Therefore, schedules must be generated in such a way that the total resource demand does not exceed the resource supply up to any point in time. The goal is to find a schedule minimising total tardiness with respect to the given due dates of the jobs. A mathematical formulation and a heuristic solution approach for two variants of the problem are

presented. Computational experiments show that the proposed heuristic outperforms a state-of-the-art commercial mixed integer programming solver both in terms of solution quality and computation time.

2 - Designing a Distributed Layout using Scatter Search
Ana Raquel Xambre

Traditional layouts (such as process oriented, product oriented and cellular manufacturing systems) are presently viewed as limited in terms of flexibility. In an environment where demand is constantly changing the choice of layout is critical and, in this context, distributed layouts are considered a good alternative because they contribute to the system's flexibility, thus increasing its ability to respond to changes in the market. In a distributed layout machines are scattered along the shop floor, in a random way, in order to improve the production system routing flexibility. By not grouping equipment into functional departments, it is possible to route different products, and/or different manufacturing orders, in alternative ways taking into account the proximity of the machines and also their availability. In this work the design of a distributed layout is analyzed considering that the distribution of the machines across the shop floor should not be random. The objective is to assign all the functionally different machines into the possible locations considering the similarities between them. A similarity coefficient has been developed that considers (i) whether the equipment processes the same type of products, (ii) if there are workers that can operate different machines and (iii) if they share tools or tooling fixtures. Since the problem has a combinatorial nature, scatter search was used in order to better explore the solution space.

3 - Dynamic Matching in the TFT-LCD Cell Assembly Process
Shine-Der Lee

We consider the dynamic matching problem in the cell assembly process for producing TFT-LCD (Thin Film Transistor-Liquid Crystal Display) panel, where the mating of two components, TFT array and color filter (CF), is assembled to produce a final product, the LCD display. The dynamic matching problem is formulated as a mathematical programming model, with the objective to optimize the yield rate of the cell assembly process. In this new formulation, each panel is precut into several equal sized sub-panels. After the precut, the sub-panels are re-sequenced by the number of good displays and the lexicographic order for the location of good displays, to reduce the modeling complexity. A yield matrix for the mating of two sub-panels is then constructed for each precut type. We explore the special structure of this new transportation model; and new properties are characterized. Based on these structures, efficient algorithms are developed for real time operation and sequencing purposes. Computational experiments with different precut types and a wide range of batch sizes indicate that the solution procedures are efficient and effective.

4 - Channel Assignment as a Distance Geometry Graph Coloring Problem
Nelson Maculan, Bruno Cardoso Dias, Rosiane deFreitas, Jayme Szwarcfiter, Philippe Michelon

In this work, we present some graph coloring models with additional constraints on the edges applying distance geometry theory, which have applications for channel assignment in mobile wireless networks. This leads to an embedding of the input graph in one dimension, where the point on the line corresponds to the color to be assigned to a vertex, according to the distance between adjacent vertices. We demonstrate feasibility conditions for some classes of graphs. Constraint and integer programming mathematical formulations are stated for the proposed models, where we use a branch-prune-and-bound framework for solving them. An empirical analysis was undertaken considering equality and inequality distance constraints, using random graphs and benchmark instances from the literature for similar problems.

■ TA-69
Tuesday, 8:30-10:00 - Livingstone LT212, Level 2

Business-driven Data Mining 2

Stream: Business Analytics and Intelligent Optimization
Invited session
Chair: *Alex Seret*

1 - The role of the data scientist in the modern organization
Jasmien Lismont, Jan Vanthienen, Bart Baesens, Wilfried Lemahieu

There seems to be general consent that data analytics entails promising opportunities and can deliver high business value. However, one also agrees that there are challenges - data issues, cultural change, organizational impact and finding the right person for the job, to name a few. Nevertheless, the application of analytics in business context seems to be growing. The goal of this study is to research the role of the data scientist and his position within modern organizations. Key research questions are: how big is the gap between in-house data scientist skills and required skills and what is the impact of introducing a chief analytics officer? Furthermore, to what extent does a centralized, decentralized or intermediate approach to the organizational embedding of data scientists have an influence on the impact of analytics? Moreover, how can firms train their data scientists and empower them towards a more mature analytics culture? By means of survey research we aim to provide an answer to these questions. The survey has a descriptive purpose and is designed in a cross-sectional manner. This study contributes to the research domain with new insights about the state of the art in applying analytics and provides a useful context for a competence framework. Furthermore, it contributes to management practices by offering a benchmark and general guidelines towards a more mature organization of data scientists.

2 - Hierarchical sales forecasting for The Coca-Cola Company: a time series benchmark and initial tool optimization
Tine Van Calster, Wilfried Lemahieu, Bart Baesens

Hierarchical forecasting with time series has been approached with top-down and bottom-up methods, which have both resulted in satisfying error rates on the most local level. This paper applies bottom-up forecasting to acquire a global sales prediction for The Coca-Cola Company, while assessing the method's accuracy for multiple large hierarchies. We take the first step in achieving these goals by experimenting with two five-step hierarchies, namely a geographical structure and a product hierarchy, and their combination levels. The first experiments centre around a forecasting tool and its optimization according to the correlation between the short-term prediction horizon and the number of training years that were required for the model. Concretely, the tool seeks to find the optimal combination of hierarchy levels to aggregate over, in order to achieve the most accurate global sales estimate. Furthermore, our findings indicate that there is a limit to the locality that the Holt-Winters triple exponential smoothing model can cope with for global prediction. Subsequently, we delimited the capabilities of this time series analysis for our case study and adjusted the tool accordingly, in order to achieve both accurate and time efficient results. To conclude, a high-level forecast with time series entails delicate balances of the optimization of the model's parameters and of capturing the correct amount of specificity without the unfavourable interference of external factors.

3 - Effects of community-based churn detection in the telecom sector.
María Óskarsdóttir, Jan Vanthienen, Bart Baesens, Véronique Van Vlasselaer, Aimée Backiel

In many applications, identifying potential churners is of great importance and has been widely studied. Recently, literature has acknowledged the power of social network analysis for churn detection, which has been proven to achieve more accurate results. We focus on churn detection in the telecommunications industry, where a social network is constructed based on call records. We contribute by evaluating and comparing two community detection approaches and, as a result, identify the effects of peer pressure on the likelihood of individuals to churn. Particularly, we propose a two-step procedure. In a first step, we detect the relevant communities of the social network using two different methods: (1) a top-down clustering approach, and (2) a bottom-up clustering approach. The top-down clustering approach results in few and large clusters, whereas the bottom-up clustering identifies complete cliques and hence produces smaller but a greater number of clusters. In a second step, we enrich churn prediction models, which traditionally only use intrinsic features. From the clusters, we extract community features and use them as additional variables to predict customer churn. Finally, we benchmark both above mentioned community detection approaches to results from the whole, un clustered network and determine which of the clustering techniques excels. Our results show how pre-clustering techniques boost the performance of churn prediction methods.

4 - Some operational challenges of customer segmentation inspired by real-life projects
Alex Seret

Data mining techniques are widely used by researchers and companies in order to solve problems in a myriad of domains. While these techniques are being adopted and used in daily activities, new operational challenges are encountered concerning the steps following this adoption. In this paper, the problem of updating and improving an existing clustering model by adding relevant new variables is studied. A relevant variable is here defined as a feature which is highly correlated with the current structure of the data, since our main goal is to improve the model by adding new information to the current segmentation, but without modifying it significantly. For this purpose, a general framework is proposed, and subsequently applied in a real business context involving an event organizer facing this problem. Based on extensive experiments based on real data, the performance of the proposed approach is compared to existing methods using different evaluation metrics, leading to the conclusion that the proposed technique is performing better for this specific problem. Other operational problems encountered during these experiments are also described in this work, e.g. the dynamics present in the customer base studied in this project.

■ TA-70

Tuesday, 8:30-10:00 - Livingstone LT303, Level 3

Information and Intelligent Systems

Stream: Information and Intelligent Systems
Invited session
Chair: *Gerhard-Wilhelm Weber*
Chair: *Nobuo Iizuka*

1 - What Have we Learned from a Monthly Survey of Professional Forecasters?: Evidence from 10 Years of ESP Forecast Survey Experience in Japan
Nobuo Iizuka

The ESP Forecast Survey (ESPF) is the first monthly survey of macroeconomic forecasts conducted by professional forecasters in Japan. The survey was launched in 2004 and conducted by the Association for Economic Planning. In 2012, the Japan Center for Economic Research took over this survey. Previously, only an annual surveys of macroeconomic forecasts were conducted. However, the introduction of ESPF has made it possible to observe monthly changes in macroeconomic forecasts. This paper examines ten years' ESPF data from the following three aspects. First, the relationship between forecast errors of annual data and the forecast horizon indicates that the mean absolute error (MAE) of annual macroeconomic forecasts begins to decrease after forecasters acquire actual data for the 1st quarter. Second, the relationship between the directional accuracy of a business cycle phase's forecasts and forecast horizon suggests that forecasts with horizons up to four months are reliable. Third, the relationship between forecast dispersion within professional forecasters and the situation of the business cycle suggests that dispersion tends to increase around the peaks and decrease around the troughs of the business cycle.

2 - New mathematical model about the relation between the project risks and the time
Hirokatsu Fukuda, Hiroaki Kuwano

Project risk is an uncertain event that causes positive or negative effects on the project objectives in relation to the cost and time to complete the project, the quality and so on. Project risk management is the set of processes of identifying, analyzing and responding to project risks. For example, the project risk management includes the process of eliminating the project risks from the project to complete any activities in the project by the specified day. In terms of not only the risks but also the time, many researches have been done. Especially, as for the time, there are many researches on CPM and PERT, which use mathematical techniques. However, few researches discuss the relation between the project risks and the time. In our research, we propose a new mathematical model that describes the relation between the project risks and the time. And with this mathematical model, we try to define the decision-making problem in the practical project risk management. Furthermore, we show how to calculate the effectiveness to eliminate the specified risk from the project. By these results we can decide quantitatively which risk should be eliminated from the project.

3 - Stresstest procedure for feature selection algorithms
Vadim Strijov, Alexandr Katrutsa

This study investigates the multicollinearity problem and the performance of feature selection methods in case of data sets have multicollinear features. We propose a stresstest procedure for a set of feature selection methods. This procedure generates test data sets with various configurations of the target vector and features. This procedure provides more complex investigations of feature selection methods than procedures described in papers previously. A number of some multicollinear features are inserted in every configuration. A feature selection method results a set of selected features for given test data set. To compare given feature selection methods the procedure uses several quality measures. A criterion of the selected features redundancy is proposed. This criterion estimates number of multicollinear features among the selected ones. To detect multicollinearity it uses the eigensystem of the parameter covariance matrix. In computational experiments we consider the following illustrative methods: Lasso, Elastic-Net, LARS, Ridge, Stepwise and Genetic algorithm and determine the best one, which solve the multicollinearity problem for every considered data set configuration.

4 - Data Centres' Adaptive Strength Geo-Replication Strategy
Amadeo Asco

Databases are a crucial component in modern information systems which have become the main bottleneck in most systems. The amount of data being processed in Data Centres (DCs) keeps growing at an enormous rate. One of the current approaches used to improve in availability and accessibility is the replication of the data in all the DCs.

The location of a DC in respect of the client accessing the data has an impact on availability, access times and costs derived from providing the data. Replicating some of the data at multiple sites is a possible solution to reduce some of these undesirable effects. An increase in the number of replications may result in a large bandwidth savings and lead to a reduction in user response time on reads or writes. But keeping too many replicas of the data incurs in extra costs, such as extra replication traffic to keep all versions of the data coherent, extra required storage and extra computational power. The control of the number of replicas of a given data is one of the main approaches to reduce such drawback. The problem of finding an optimal geo-replication schema in a general network has been shown to be NP-complete.

Given this we have designed an adaptive replication algorithm, named Adaptive Strength Geo—Replication Strategy (ASGRS), which dynamically takes account of the users data access patterns to identify what data, when, where and how many times to replicate the data in an efficient way.

■ TA-71

Tuesday, 8:30-10:00 - Livingstone LT307, Level 3

Graphs and Applications

Stream: Graphs and Networks
Invited session
Chair: *Cédric Bentz*

1 - A Survey on Minimum d-Modifications Problems in Graphs
Christophe Picouleau

A d-modification problem in graphs is defined as follows: given a class of graphs B, a set of one or more graph operations S, and a graph parameter p. The question is whether a graph G in the class B can be modified, by using at most k operations from S, into a graph H such that magnitude between the parameter computed for G minus the parameter computed for H is at least d for some threshold d, which is a non-negative integer that can either be fixed or be part of the input.

We survey the main results in this field where the graph parameters that were considered are the chromatic number, clique number, independence number, matching number, and the vertex cover number, while the set S was a singleton consisting of a vertex deletion, edge deletion or edge addition, edge contraction.

2 - An Approximation Algorithm for Packing Steiner Trees under Budget and Delay Constraints
Thibaut Lefebvre, Cédric Bentz, Eric Gourdin, Sourour Elloumi

Given a network with, for each edge, a capacity, a delay, and a cost, we consider the problem of fractionally packing Steiner trees under capacity, budget, and delay constraints. This kind of problem arises in telecommunication applications, where one wishes to send as much information as possible to a set of clients through a network, while ensuring a given level of quality of service and under a given budget constraint. Steiner tree problems naturally appear in the framework of multicast routing, where any node in the network is allowed to replicate its input data to release an information flow on its outputs. In this paper, we extend existing models of Steiner trees packing by incorporating budget and delay constraints. We first formalize this problem, then we give an approximation algorithm inspired by the method proposed by Garg and Könemann which solve it, provided its dual separation problem can be approximated. Hence, we obtain complexity and approximation results for several special cases of our packing problem.

3 - A Practical Greedy Approximation for the Directed Steiner Tree Problem
Dimitri Watel, Marc-Antoine Weisser

The Directed Steiner Tree (DST) NP-hard problem asks, considering a directed weighted graph, a node called root and a set of nodes called terminals, for a minimum weight directed tree rooted at the root spanning the terminals. The best known polynomial approximation ratio for DST is the algorithm of Charikar et al. (CH), which is a greedy algorithm. However, a much faster approximation, the shortest paths algorithm (SHP), returning the shortest paths from the root to each terminal, is generally used in practice although the ratio of CH is better than the ratio of SHP.

The main idea of CH is to search for partial solutions with small density : the tree may cover only a part of the terminals but the weight per terminal covered by the tree should be small. When such a solution is built, the covered terminals are removed and the algorithm repeats those two steps until there is no more terminal. The smaller are the densities, the smaller is the approximation ratio. The choice, in pratice, to use SHP instead of CH is due to the first step, searching for small density trees, which is slow.

We provide three variants of a new algorithm based on a fast way to exhibit partial solutions with small density. Our computational results show that our algorithms rival in practice with the running time of SHP and return solution with smaller cost in practice.

4 - Complexity of Grundy Coloring and its Variants
Florian Sikora, Edouard Bonnet, Florent Foucaud, Eunjung Kim

The Grundy number of a graph is the maximum number of colors used by the greedy coloring algorithm over all vertex orderings. In this paper, we study the computational complexity of Grundy Coloring, the problem of determining whether a given graph has Grundy number at least k. We show that Grundy Coloring can be solved in moderately exponential time. While the problem is known to be solvable in time FPT time with parameter (k,w) for graphs of treewidth w, we prove some lower bound under the Exponential Time Hypothesis. We also study the parameterized complexity of Grundy Coloring parameterized by the number of colors, showing that it is in FPT for graphs including chordal graphs, claw-free graphs, and graphs excluding a fixed minor.

Finally, we consider two previously studied variants of Grundy Coloring, namely Weak Grundy Coloring and Connected Grundy Coloring. We show that Weak Grundy Coloring is fixed-parameter tractable with respect to the weak Grundy number. In stark contrast, it turns out that checking whether a given graph has connected Grundy number at least k is NP-complete already for k=7.

■ TA-73
Tuesday, 8:30-10:00 - Collins CL205, Level 2

Demand Forecasting

Stream: Forecasting & Time Series Prediction
Invited session
Chair: *Aris Syntetos*

1 - Demand forecasting with a fuzzy linear regression methodology: a case study at a medical assistance company
Ferhan Çebi, Aierxiati Aikeshan, Aycan Kaya

This study aims to present a mathematical model to help the organization to make more accurant demand forecasting under fuzzy environment. This model is applied to solve the demand forecasting problem of a newly founded medical assistance company in Turkey. The company, as a newly founded one, has lack of statistical data for predicting its future demand and while dealing with insufficient data, the usage of deterministic forecasting methods can not yield efficient results in decision making process. However, the fuzzy linear regression methodology developed by Tanaka, Uejima and Asai in 1982 can overcome the above-mentioned risk during the design of demand forecast models by taking the fuzziness of relationship between input and output values. While developing fuzzy regression model, we discuss with the management of the company about the factors affecting demand and five independent variables are determined as the number of tourists coming to Turkey, number of road accidents, the number of contracted hospitals, average temperature in the country, number of work permits, whereas dependent variable is taken as the number of processing customer files. The results obtained from fuzzy regression model is comparatively analysed with the results of the linear regression model.

2 - Do sales depend on search traffic? The case of video games
Oliver Schaer, Nikolaos Kourentzes

Public available search engine (SE) data such as from Google Trend can offer insights on the search interest for a specific product. Nowadays, customers often use search engines to inform themselves about a product prior to the purchase. This permits new modelling approaches that can improve forecasting accuracy by using it as a leading indicator. Several studies already focused on the correlation of SE data and actual sales but rather focused on brand-level or initial phase of a new product only. This study focuses on describing the relationship between search engine and sales data considering the entire product life span using weekly video games sales data. At first, we evaluate the suitability of search volume data as a leading indicator and focus especially on the detection of causal dependency, overcoming a common limitation in many studies using SE data. In particular, exploring the direction of causality is interesting, as during the mature phase of a product, search traffic can also be caused by users of already sold entities and therefore may no longer be causal of new sales. According to those findings we propose appropriate forecasting models that incorporate SE data for short and long-term forecasting and evaluate their accuracy using real sales data from the gaming industry.

3 - Forecasting returns and demand in a military closed loop supply chain
Thanos Goltsos, Aris Syntetos, George Ioannou, Andrew Hopkins, Ashley Shaw

Remanufacturing is the industrial process that restores used products (cores) to an as-new state. Core acquisition management (CAM) is the active management of the reverse supply chain of cores, in terms of quantity, time and quality. Forecasting of returns is the stepping stone towards effective CAM and inventory control. Remanufacturers have found this to be very challenging due to the high complexity and uncertainty involved in the return process. Existing literature is extremely sparse in its exploration of suitable forecasting tools within a remanufacturing context. This work considers the forecasting challenges faced by a UK based non-hybrid service-contract remanufacturer and supplier of spare parts, part of a closed loop military supply chain. To this end, we have considered and applied various classification schemes and forecasting methods, adapted to the realities of the problem studied. We work with 9 consecutive years of demand and returns data of intermittent nature. For the reverse loop, we produce forecasts for the return of cores in terms of time, quantity and quality. For the forward loop, we forecast the demand for remanufactured cores, parts used in remanufacturing process, and for spare parts supplied independently. The proposed forecasting methodology delivers considerable benefits to the company. When benchmarked against the existing judgementally intervened forecasting system, it is shown to lead to important forecast accuracy improvements.

4 - Forecasting of compound Erlang demand
Aris Syntetos, Mohamed Zied Babai, Shuxin Luo

Intermittent demand items dominate service and repair inventories in many industries and they are known to be the source of dramatic inefficiencies in the defense sector. However, research in forecasting such items has been rather limited. Previous work in this area has been developed upon the assumption of a Bernoulli or a Poisson demand arrival process. Nevertheless, intermittent demand patterns may often deviate from the memory-less assumption. In this work we extend analytically previous important results to model intermittent demand based on a compound Erlang process, and we provide a comprehensive categorisation scheme to be used for forecasting purposes. In a numerical investigation we assess the benefit of departing from the memory-less assumption and we provide insights into how the degree of determinism inherent in the process affects forecast accuracy. Operationalised suggestions are offered to managers and software manufacturers dealing with intermittent demand items.

■ TA-77
Tuesday, 8:30-10:00 - Collins Insight Institute

Behavioural issues in Decision Analysis II

Stream: Behavioural Operational Research
Invited session
Chair: *Etienne Rouwette*

1 - Processing of information via decision making protocols
Lisette Firet, Etienne Rouwette, J. Vennix

Decision making protocols (DMPs) structure decision processes and aim to standardize reasoning. Do different people indeed process DMPs identically, resulting in identical solutions to a task? Dual process theories distinguish reasoning into the intuitive system 1 and the reflective system 2. Does the availability of an intuitive solution, influence DMP processing? Our findings indicate that DMPs do not standardize reasoning across people, but instead diversity in decision-making processes and decision outcomes. 146 participants solved two problems each, using a given elementary DMP. A rich variation in DMP routes taken was found. 44.5% of the routes taken through the DMP deviated from the standard route to the problem solution. A third of the problems triggered an initial intuitive solution. The initial intuitive solution was given as final answer in 16.7% of the tasks, despite the fact that the DMP generally offered a different solution. This indicates that either a participant processed the DMP in the direction of his intuitive answer, or intuition overruled the DMP outcome. All participants took the Cognitive Reflection Test (CRT) (Frederick, 2005). Although absolute numbers are small, the majority that chooses their intuitive answer as a final answer had a high CRT-score. This does not match the expectation that a high CRT-score lowers the inclination to use intuitive decision-making (Stanovich and West, 2000; Johnson-Laird and Khemlani, 2013).

2 - Preference stability over time using two weight elicitation methods for wastewater infrastructure planning
Judit Lienert, Mert Duygan, Jun Zheng

To support decisions in practice, MCDA relies on eliciting preferences from decision makers, e.g. weights. Weight elicitation is tricky and prone to biases. Especially for long-term environmental decisions, the preference parameters entering the decision model should be reliable, also over time. Our experiment concerns wastewater infrastructures using two online surveys among the public and our research institute. Weights were elicited with SWING and a variant of the SMART/SWING-method. To test preference stability, we repeated the survey after one month and analyzed the proportion of rank reversals and sum of absolute differences in weights between the first (N=314) and second survey (N=200). The SWING-method was perceived as more difficult, but respondents of the SMART/SWING-variant felt more certain. SWING produced more stable preferences (32% rank reversals; 50% with SMART/SWING-variant). The relationship between preference stability and other explanatory variables (e.g. knowledge) will be discussed. Acquiring new experience between surveys significantly changed preferences, i.e. people updated judgments. In real decisions, statistically significant differences of

preferences elicited with different methods may not lead to different ranks of alternatives. Thus we present results about the importance of effects, based on an MCDA in a real Swiss case study. We discuss limitations of our experiment and suggest future behavioral research to improve practical decision-making.

3 - Facilitating non-expert use of decision analytical models
Kinga Lowrie

There is an emerging paradigm which proposes that decision makers should be given the opportunity to interact with Decision Analytical Models as this can play an important role in communicating economic evidence, especially to stakeholders on a local level. However, when decision makers need to interact with the model it can be argued that usability of such tools becomes integral to an assessment of its value. As part of the Mainstreaming Assisted Living Technologies (MALT) project, we developed a cost-effectiveness model with an integrated financial planning tool for Telehealth services, and tested its usability in a series of Think Aloud experiments with 16 end-users. Several usability problems have been detected during these tests, which above all revealed participants' cognitive processes during problem solving. As a result, several improvements have been implemented to the design of the interface. Overall feedback suggested that when appropriately adjusted to its users, models can be successfully used by non-experts.

4 - Two possible pitfalls when importing behavioural science to OR; and a demonstration in military stability operations
Konstantinos Katsikopoulos, Niklas Keller

There is now a momentum for importing methods and knowledge from psychology to operational research. The main aim of this talk is to use the cases of behavioural economics and behavioural operations management to discuss two possible pitfalls in the import of psychological science to operational research. These pitfalls can disrupt two important goals of behavioural operational research: Building models that (1) describe how people behave and (2) prescribe how people should behave. The discussion draws from literature useful to operational researchers and yet little known. On (1), we argue that many popular models of human behaviour have been over-fitted to laboratory data and do not specify the underlying psychological processes. On (2), we argue that there is a neglect of theory of when people's heuristics are an asset and little use of heuristics in guiding decision processes. The second aim of this talk is to demonstrate how to avoid these two pitfalls and to show empirically the benefits of doing so, in the specific problem of reducing civilian casualties in military stability operations. Using 1,060 reports from NATO checkpoints in Afghanistan between 2004 and 2009, it is shown how a fast and simple graphical aid would have reduced civilian casualties by over 60%, while simultaneously enhancing soldier safety.

■ TA-78
Tuesday, 8:30-10:00 - Architecture AR201, Level 2

Community OR

Stream: Community OR
Invited session
Chair: *Eliseo Vilalta-Perdomo*
Chair: *Martha Vahl*

1 - ConnectEd Communities? -The role of networks and social capital in the International Student Experience
Jennifer Jackson

In 201/12 non EU students accounted for 33.5% of the UK Higher Education sector's income from tuition fees and education contracts, whilst the off campus expenditure of international students (EU and non-EU) was estimated at £4.9 billion. What is less known is the social impact and connections that it generates, what is the reality of the students 'globalisation' experience and networks, compared to the intentions and expectations? This paper explores qualitative research currently being undertaken at the University of Lincoln's Business school to understand more about the dynamics of what constitutes the narrative of being an 'international student'.

2 - Food Supply Arrangements
Eliseo Vilalta Perdomo, Martin Hingley

Businesses integrate in different food supply arrangements (FSAs) to create economic value. Ways to increase that value are traditionally associated with sharing expectations and aligning outcomes from different participants. However, in the case of micro-producers, increasing economic value is not the only motivation to engage with such arrangements. In their case other drivers have been identified which suggest the need for a complementary approach in order to realise their individual development. In this paper, we analyse four different arrangements for food supply design: direct distribution channels, supply chains, supply networks and supply communities. Elements such as challenge addressed, main driver, organisational principle, transactional direction and power structure are considered to provide a new description for the preference to a particular supply arrangement. Our contribution extends the notion of multi-actor supply arrangements beyond chains and networks, by considering supply communities that involve producers and consumers. We introduce the notion of 'community' and use it to propose micro-producers as members of internally self-organised communities that may engage in the development of individual and collective supportive actions. To contextualise the discussion, we use the case of a typical UK regional, county-based food marketing group which provides umbrella marketing support for specialist SME and micro food businesses.

3 - Community OR: More data as an strategy to deal with societal challenges
Martha Vahl

OR developed after WWII as a forum to discuss and improve purposeful actions by looking at better ways of organising individual and/or collective efforts. Notwithstanding various changes, including the ability to collect and analyse massive amounts of data, this objective does not seem to have changed. Results still have to be used - but preferably such that this does not damage others, e.g. stakeholders. This suggests an interest in the modification and improvement of objectives and values such as quality of life, services available, work availability, public investment, transportation and elderly care, among many others. This stream is a platform to discuss improvements on this kind of experience. It requires that the focus is on interactions, for example in community life.

■ TA-79

Tuesday, 8:30-10:00 - Architecture AR310, Level 3

Sports Analytics

Stream: OR in Sports
Invited session
Chair: *Dries Goossens*

1 - The team formation problems in different stages for multi-player sports.
Gercek Budak, Imdat Kara

The decision maker(s) of the sports clubs, concerned with the team formation problem, decide(s) which players to put on their team. The dimensions of these decision problems became more complex and coaches are unable to make a systematical decision by themselves. Depending on those circumstances, these problems are becoming more complex than before. As the sector becomes larger by means of finance and as data collection becomes easier and prevalent in sports, these problems are becoming popular. There exists a few researches on this subject in the Operations Research literature. In this paper, team formation decisions are grouped in three stages. The first stage is a long term decision and is made once before each season begins. The mid-term decisions are done once before each match and those are periodic decisions for every match. The short term decisions can be identified as the decisions made during the match, which concern to make changes in the line-up. We discuss and describe decisions on each stage in terms of the decisions variables, constraints/ restrictions and objectives verbally. For mid-term decisions, we showed how to use Analytic Hierarchy Process method for weighting the skills required for each position of the game. We conclude that the integrity of decision processes of the stages has to be considered while modelling the problem.

2 - Investigating different scoring structures for win-draw-loss in football
Tim McGarry, Bram Russell

Scoring structures for win-draw-loss (W-D-L) sports results affect tournament outcomes. In the English Premier League (EPL), the change from 2-1-0 to 3-1-0, designed to reward attacking play by biasing points for a win, sometimes affected team rankings, as expected, including the top four and bottom three, with important consequences for the football clubs in question. Scoring structures, 3-1-0: 3-2-0 and 3-1-0: 4-2-0, representing W-D-L points for home and away teams, respectively, were also investigated. Understandably, both structures reduced home advantage effects, a possible consideration for tournament administrators. The shift from 2-1-0 to 3-1-0 changes the scoring structure from balanced to imbalanced, as game points for a win in the latter is higher than the shared spoils for a tied result. The 3-1-0: 3-2-0 structure is balanced too, as is breaking a draw by other means and assigning two points and one point to the winning and losing teams, respectively. Penalty shout-outs are used to break tied outcomes in knock-out games, and their proposed use in league competition would also serve teams well in future international competition. This approach is shown to reward weaker teams at the expense of stronger teams under certain conditions, thus making the EPL more competitive, an attraction for tournament administrators. This finding decreases the efficacy of the tournament structure however, as the ability to discriminate the strongest from the weakest teams is reduced.

3 - Analyzing fantasy sport games results using mixed integer programming
Jeroen Belien, Dries Goossens

In a fantasy sport game, participants act like a team manager building a team of real individual players of a professional sport. The real performances of these players (or their teams) are translated into points for their team managers. The managers' aim is to collect as many points as possible thereby defeating the fantasy teams of opponents. Based on a number of common characteristics, we present a general mixed integer programming model that can be used to analyze the ex-post results of fantasy sport games. The computational performance of the model is illustrated using real-life data from an online fantasy cycling game. We discuss the impact of certain game features on the required computation time and present the results of some speed-up techniques like the use of valid inequalities. Finally, we demonstrate how the results can be used to (1) obtain general insights into good game strategies, (2) provide individual feedback for each participant, and (3) create business value for the game organizer.

■ TA-80

Tuesday, 8:30-10:00 - Architecture AR311, Level 3

Transportation Networks

Stream: Transportation Planning
Invited session
Chair: *Frank Meisel*

1 - Optimizing Petrol Distribution to a Stations Network
Luis Moreno, Juan Esteban Calle Salazar, David Felipe Higuita Alzate

This work takes into account the details involved in urban and national distribution combined: aspects such us revisiting the supplier several times in a period (situation presented in urban distribution networks) and the sleeping time of the driver on the road for long periods (situation presented in national distribution networks). Performance of two models are compared, one that minimizes the travel, vehicle fixed and inventory holding costs and another that doesn't take into account the fixed cost of using a vehicle. Another matter experimented in the model is the use of surrogate constraints, showing better computational time when they are not used. For reducing the domain of the problem, and consequently the computing time, connections between nodes that are far away arent considered. Based on distances from which connections are not considered, the deterioration in the objective function vs the speed earned in the solution process is analyzed. The model was implemented in AIMMS and solved with Gurobi 6.1.

2 - Robust Distribution Network Design: A Case Study in the Frozen Food industry

Amin Chaabane, Ramin Geramianfar

In this work, we deal with a food distribution problem that can be considered as a generalization of the multi-period production distribution network design problem. In particular, we are involved with a real application related to a Canadian company that holds food markets in North America and has to determine the strategic location of 3PLs and tactical allocation decision of inventories for a two echelon supply chain. Preliminary results with deterministic data suggest that companies using efficient forecasting policies tend to reduce the number of third party logistics and may enjoy cost reduction. The model is then extended to integrate uncertainty in key input parameters. Numerical results obtained from model implementation and sensitivity analysis experiments arrive at important managerial insights and practical implications.

3 - Generalizations of the Classical Transportation Problem

Annette Ficker, Frits Spieksma

In the classical Transportation Problem we are given a set of suppliers that each have a supply, and a set of locations each with a demand. For each pair of supplier and location we are given a unit transportation cost. The goal is to fulfill the demand with minimum cost. This problem is well-known and efficiently solvable. However, there are many situations in practice that require additional constraints; we give two examples. In one example patients (supply) need to be assigned to hospital rooms (demand), with the additional constraint that each room should only contain patients of the same gender. This example gives rise to the so-called Red-Blue Transportation Problem (RBTP). Another example comes from storage management where containers (supply) need to be placed in rows of a storage yards (demand), such that costs of operations (search, load) is minimized. However, some containers are not allowed to be placed in the same row. This example gives rise to the Transportation Problem with Exclusionary Side Constraints (TPESC), which we show to be more general than the RBTP.

We present results concerning the complexity of these problems, and describe approximations algorithms for solving them.

■ TA-82

Tuesday, 8:30-10:00 - Architecture AR401b, Level 4

Health Care Service Operations

Stream: Healthcare Service Improvement
Invited session
Chair: *Inês Marques*

1 - A Surgical Case Assignment Problem in a Block Scheduling Strategy

Inês Marques, Maria Eugénia Captivo

An adequate access to healthcare is one of the strategic axes considered in the Portuguese National Health Plan. The demand for surgical care in Portugal tends to grow continuously ever since a systematic measurement was introduced. Hospitals are forced to make the most appropriate use of available resources in order to provide timely care to surgical requests. This work emerges from a close collaboration with the Administration of a publicly funded Portuguese hospital. This hospital has a central operating theatre with a large number of operating rooms shared by several specialties. The operating room time is pre-allocated to specialties (master surgery schedule) and each specialty schedules surgeries to its allocated time block and day (block scheduling strategy). In advance scheduling, also referred to as surgical case assignment problem (SCAP), patients waiting for surgery (elective patients) are assigned to an operating room and a day in a weekly planning horizon. Two versions (the Administration's intention and the surgeon's current practice) are modeled using (mixed) integer programming. In preliminary results using hospital data, Cplex provided a feasible solution with a gap smaller than 1% in negligible time.

2 - A Real Life Operating Room Scheduling Problem

Elvin Coban, Gulsah Alper

We study a real life operating room scheduling problem using a dataset from a leading hospital in Turkey. We solve the daily and weekly scheduling problems by a mixed integer linear programming model. Various objective functions and performance metrics are analyzed including minimizing the waiting time of patients while maximizing fairness between utilized operating rooms. We examine surgery delays and incorporate possible delays in surgery durations. We also propose a method to compute robust operating room schedules.

■ TA-84

Tuesday, 8:30-10:00 - Architecture AR403, Level 4

Optimization in Bioinformatics

Stream: Computational Biology, Bioinformatics and Medicine
Invited session
Chair: *Aleksandra Swiercz*

1 - Optimization Model Applied to Chemical, Biological and Physical Dengue Control

Daniela Cantane, Helenice Florentino, Fernando L. P. Santos, Célia Reis, Margarida Pato, Dylan Jones, Rogerio Antonio de Oliveira, Marianna Cerasuolo, Luiz Lyra

The incidence of dengue has grown dramatically around the world in recent years and has a high rate of mortality. Dengue is a febrile infectious disease, which is transmitted by the bite of female mosquitoes of the species Aedes aegypti. The World Health Organization (WHO) estimates that 390 million people are infected in more than 100 countries from all continents, in tropical and sub-tropical areas. Currently as no dengue vaccine has been developed for human application, mosquito control is the only known method to protect human populations from dengue fever. The most used controls are physical and chemical. Possible alternatives are genetic and biological controls. In this paper, we propose an optimization model to investigate the intensity of three types of mosquito control: physical (removal of breeding), chemical (by spreading insecticide) and biological (by introducing sterilized mosquito males). The objective function simultaneously minimizes the damage of the insecticide, the costs of production and insertion of the sterilized mosquitoes in nature, the number of fertilized females, the effect of the insecticide on sterilized mosquitoes and the amount of breeding. A genetic algorithm is proposed to determine feasible solutions for the optimization problem. The computational experiments shows efficiency in achieving control of the mosquito population.

2 - Optimal Discretization of Continuous Features for Mining Gene Expression Data

Daniele Santoni, Emanuel Weitschek, Giovanni Felici

In this work we consider a class of methods designed for classification and data analysis applied to gene expression data obtained by microarray or NGS experiments. We focus on gene expression discretization, analyse the main issues related to this problem and propose an optimization model where the problem is to take into account the dependence between features and samples. An efficient solution algorithm for large problems is described, and comparisons with other discretization methods are provided. Practical results on microarray data conclude the presentation.

3 - Hyper-heuristics with Unified Encoding for Combinatorial and Bioinformatics Problems

Aleksandra Swiercz, Jacek Blazewicz, Edmund Burke, Mateusz Cichenski, Grzegorz Pawlak, Sanja Petrovic, Tomasz Zurkowski

We introduce an approach to applying hyper-heuristic algorithms to solve combinatorial problems with less effort, considering the time needed for the algorithm construction process. A hyper-heuristic algorithm operates on a set of low level heuristics, rather than on a direct representation of the problem. We proposed a unified encoding of a solution for different problems and a set of low level heuristics which are domain-independent and which change the solution itself. This approach enables to solve NP-hard problems giving good approximate

solution in a reasonable time without a large amount of additional work required to tailor search methodologies for other problems in hand. In particular, we focused on solving DNA sequencing by hybrydization problem which is known to be strongly NP-hard. The approach was extensively tested by solving multiple instances of well-known combinatorial problems and compared to the results of metaheuristics tailored for specific problem domains.

Tuesday, 10:30-12:00

■ TB-01

Tuesday, 10:30-12:00 - Barony Great Hall

Tutorial Lecture: Martin Savelsbergh

Stream: Plenary, Keynote and Tutorial Sessions
Tutorial session
Chair: *Claudia Archetti*

1 - Advances in Criterion Space Search Methods for Multiobjective Mixed Integer Programming
Martin Savelsbergh

Many real-world problems involve multiple objectives. Due to conflict between objectives, finding a feasible solution that simultaneously optimizes all objectives is usually impossible. Consequently, in practice, decision makers want to understand the trade-off between objectives before choosing a suitable solution. Thus, generating many or all efficient solutions, i.e., solutions in which it is impossible to improve the value of one objective without a deterioration in the value of at least one other objective, is the primary goal in multiobjective optimization. Recently, a number of studies have shown that solving instances of multiobjective integer programs with two and three objectives of reasonable size is now within the realm of possibilities. Furthermore, some of these algorithms, e.g., the rectangle splitting method and the L-shape method, can produce high-quality approximate efficient frontiers quickly. We will present an overview of algorithms for solving multiobjective integer programs with a focus on criterion space search methods.

■ TB-02

Tuesday, 10:30-12:00 - Barony Bicentenary Hall

EURO Doctoral Dissertation Award, part I

Stream: EURO Awards and Journals
Award Competition session
Chair: *Hartmut Stadtler*

1 - Robustness and Recoverability in Transport Logistics
Luis Cadarso

It is widely accepted that operations research can help in efficiently planning the design and operating transport systems. This dissertation makes contributions to the application of operations research in rail and air passenger transport and studies their interactions. We develop several mathematical models which answer to several RENFE's and IBERIA's (the major railway operator and airline in Spain, respectively) problems. Examples of these problems include passenger behaviour modelling, schedule planning, resources scheduling, and disruption management. We also study the integration of the subsequent planning stages and the competition between the rail and air modes. We incorporate important and timely problem attributes and objectives such as robustness and show that solutions can better deal with the unavoidable disturbances occurring in transport networks. Because we deal with real-world problem instances and some of the problems need real time solutions we design and implement tractable solution approaches. The obtained results have been positively received by our industrial partners.

2 - Spare Parts Planning and Control for Maintenance Operations
Joachim Arts

Interchangeable parts have revolutionized modern manufacturing. However, the idea of interchangeable parts was originally a maintenance innovation. Equipment that represents a significant financial investment (e.g. aircraft, rolling stock and MRI scanners) is usually maintained by replacing parts in need of maintenance with ready-for-use parts. In this manner, downtime of equipment due to maintenance can be kept to a minimum. To make this system work, it is crucial to

have the right amount of spare parts available. This thesis is dedicated to questions that planners os spare part supply chains face regularly, such as: How many spare parts to buy? How to schedule overhauls of important parts? When should the repair of a spare part be expedited? To aid in making these decisions, we formulate mathematical models to gain structural insights and develop practical solution algorithms. Important features, such as multiple types of spare parts and shared capacities, are incorporated. This research was conducted in collaboration with our industrial partner, NedTrain. The analysis of models uses techniques from different branches of operational research including hierarchical decomposition, mixed integer programming, Markov decision processes, numerical inversion of generating functions, Lagrangian decomposition and column generation, Markov chain aggregation, and asymptotics.

■ TB-03

Tuesday, 10:30-12:00 - TIC Auditorium A, Level 2

Meet the Editors of EJOR

Stream: EURO Awards and Journals
Meeting session
Chair: *Roman Slowinski*

1 - Some Facts about the European Journal of Operational Research (EJOR)
Roman Slowinski, Immanuel Bomze, Emanuele Borgonovo, Robert Dyson, José Fernando Oliveira, Ruud Teunter

The editors of EJOR will give some characteristics of the journal, and will explain their approach to evaluation and selection of articles. They will point out topics of OR which recently raised the highest interest. Two other presentations in the session will be done by authors of representative and highly cited papers published recently in EJOR. In the last part of the session, the editors will answer some general questions from the audience.

2 - An adaptive large neighborhood search heuristic for the Pollution-Routing Problem
Tolga Bektas, Emrah Demir, Gilbert Laporte

The Pollution-Routing Problem (PRP) is a recently introduced extension of the classical Vehicle Routing Problem with Time Windows which consists of routing a number of vehicles to serve a set of customers, and determining their speed on each route segment so as to minimize a function comprising fuel, emission and driver costs. This talk will describe an adaptive large neighborhood search for the PRP. Results of extensive computational experimentation will be presented.

3 - Design and Planning of Supply Chains with Integration of Reverse Logistics Activities under Demand Uncertainty
Ana Barbosa-Povoa, Susana Relvas, Sónia Cardoso

A mixed integer linear programming (MILP) formulation is developed for the design and planning of supply chains with reverse flows where simultaneously production, distribution and reverse logistics activities are considered. Products' demand uncertainty is studied using a scenario tree approach. The model defines the maximization of the expected net present value and the results provide details on sizing and location of plants, warehouses and retailers, determination of processes to install, establishment of forward and reverse flows and inventory levels to attain. The model is applied to a representative European supply chain case study and its applicability is demonstrated.

■ TB-04

Tuesday, 10:30-12:00 - TIC Auditorium B, Level 2

Retail Supply Chain Management II

Stream: Demand and Supply in Retail and Consumer Goods
Invited session
Chair: *Heinrich Kuhn*

1 - A Benders Decomposition Algorithm for Supplier Selection in the Food Supply Chain
Eduardo Curcio, Pedro Amorim, Bernardo Almada-Lobo, Ana Barbosa-Povoa, Ignacio Grossmann

In this work, an integrated framework for companies to select suppliers in processed food supply chains is addressed. A two-stage stochastic mixed-integer model that integrates strategic sourcing and both tactical production and distribution planning is proposed. The model aims at maximizing the expected profit and minimizing the risk of low customer service. It takes into account the main complexities of a food supply chain: both final products and raw materials have limited shelf life and can be spoiled; the impact of freshness on the customer demand; and there are uncertainties sources related to both suppliers and customers. In order to solve this complex problem, we develop two solution techniques based on a classical and modern Benders decomposition that are able to solve large instances efficiently. In addition, acceleration methods based on a convex hull reformulation, a multicut approach and convex combinations are implemented in order to improve the Benders convergence. Computational experiments are run to compare the performance of the monolithic model solved with a commercial solver and the Benders decomposition variants. The results show that the solution methods proposed are adequate for solving large instances of this problem.

2 - Assignments of Products to Alternative Distribution Centers in Retail Chains
Heinrich Kuhn, Andreas Holzapfel, Michael Sternbeck

The talk considers the problem of assigning stock keeping units (SKUs) to alternative distribution centers belonging to different distribution stages in a retail network, i.e., central or regional. A MIP model is presented minimizing total costs and reflecting the interdependencies between inbound transportation, outbound transportation and instore logistics

3 - Optimal Time to Reposition Inventories in Multi-Location Centralized Networks
Olga Rusyaeva, Joern Meissner

Repositioning of inventories between locations aims to decrease the impact of inventory imbalance in multi-location centralized networks, caused by e.g. imperfect demand information or delayed delivery. In practice, it is often done via lateral transshipments that are performed either reactively, when the stockout occurs, or proactively in an anticipation of future stockouts. The last approach calls an additional managerial decision, namely when to reposition inventories. As each location has two demand types, one from customers and another from other locations, the transshipment time should be chosen accurately to avoid transfers back and forth between locations, and, as a result, additional costs.

The objective of our study is to find an optimal time for proactive transshipments and optimal transshipment quantity in order to maximise the profit of a multi-location network. To this end, we decompose the problem on dynamic program to find a transshipment time and on the linear program to derive transshipments between locations. Due to the large state space of the problem, known as the curse of dimensionality of the dynamic programming, a myopic policy and a policy based on the simulation are suggested for real-size problems. We present our numerical results obtained by dynamic programming and heuristic methods, and discuss their performance. Besides that, we compare the dynamic and static solutions, and describe the situations when it pays off to apply the dynamic policy.

4 - Design of Retail Backroom Storage: A Research Opportunity
Maria Pires, Pedro Amorim

Most retail stores hold their inventory in two locations: retail shelves, in the sales area, and in the backroom storage areas. Products are stored in the backroom for many reasons but one main factor is the limited shelf space that makes it often impossible to fit a complete replenishment order on the allocated shelf space. The design of retail backroom storage has a great impact on in-store operations, customer service levels and store life-cycle costs. Moreover, backrooms are crucial in modern retail stores to several functions, such as acting as a buffer against strong demand lifts yielded by an ever increasing promotional activity, seasonal demand peaks, and accommodating e-commerce activities. Since these warehouses are integrated in stores, they face additional challenges such as coexisting and interacting with the selling area, which also competes for both space and resources. This research aims to draw attention to the design of backroom storage areas, since most of the existing literature has focused solely on

distribution centres (DC). Despite having similar functions, backroom storage facilities have particularities that deserve a distinct analysis. For instance, operations on a retail store level are more complex and unorganized than in DC. In this talk we will present a framework for the backroom storage design, highlighting the core differences against DC. Moreover, we will indicate adequate methodologies to solve the problems emerging from this framework.

■ TB-05

Tuesday, 10:30-12:00 - TIC Auditorium C, Level 2

Network Design, Supply Chain Planning, and Engineering Optimization

Stream: OR Applications in Industry
Invited session
Chair: *Geir Hasle*
Chair: *Annika Vernbro*

1 - Simulation and Optimization of Gas Transmission Networks
Ángel Manuel González Rueda, Alfredo Bermúdez, Julio González-Díaz, Francisco José González-Diéguez

In this talk we plan to present the results of an ongoing collaboration with a Spanish company in the gas industry, in which we have developed a software, GANESO, that can simulate and optimize gas transmission networks. The focus will be on the aspects more closely related with the associated optimization problem. The main challenges in this setting come from: -Nonlinearities and nonconvexities inherent to the modeling of gas flows. -Integer variables are needed to model certain operation decisions dealing with different network configurations. -A relatively large number of variables. Thus, it is very hard to solve the resulting problem with exact algorithms. The methodology we have followed consists of implementing a slight variation of the standard sequential linear programming algorithms that can easily accommodate integer variables, combined with a control theory approach. The resulting algorithm has proven to be very effective in solving the kind of problems our partner company was interested in. We will also present one of the most recent additions to GANESO optimization features: a module to study long-term infrastructure planning under uncertainty. This has been modeled as a multistage stochastic nonlinear programming problem with integer variables and the result is a parallel computing algorithm that builds upon Lagrangian decomposition ideas. Other functionalities of GANESO such as stationary and transient simulation will be briefly discussed.

2 - PrO-Lean Planning: Detail and Aggregation in Tactical Supply Chain Planning for the Chemical Industry
Annika Vernbro, Iris Heckmann, Stefan Nickel

In a typical supply chain planning environment, tactical planning is a recurring task that involves data, automated methods as well as human decisions and judgement. To achieve high quality plans under reasonable levels of planning effort one should respect three main principles: proportionality, practicability and outcome-driven design. We call this approach PrO-Lean Planning. PrO-Lean is a new paradigm for developing models and methods for tactical supply chain planning. In the light of these principles, we discuss the importance of identifying the "right' data for good decision making in tactical planning. On the one hand due to complexity, data consistency and quality the collection and maintenance of detailed planning input can be cumbersome. On the other hand some decisions require more thorough preparation than typically applied. This yields to highly granular data. With respect to proportionality we should consider just as much detail and complexity as is justified by substantial gains in plan quality. We present different planning models focusing on decision making in the chemical industry. In addition, we give preliminary results and investigate the impact of different levels of data complexity on decision quality.

3 - 3D Software Technology for Practical Realization of Special Hyperboloid Gear Mechanisms
Emilia Abadjieva, Valentin Abadjiev

The study presents description in physical prototyping and technical realization of specialized miniature spatial gears with linear contact. A feature of these gears is the necessity to realize a smooth transformation of rotations with constant values of the velocity ratio for the entire

work. They are hyperboloid gears with linear contacting active tooth surfaces at the maximum coincidence of the theoretical and the real realization of their geometric and kinematic conjugation. The achievement of the defined goal is realized by application of 3D software technology including the following stages: an optimization synthesis based on the mathematical model upon a pitch contact point; construction of 3D software model by the application of a mathematical model for synthesis upon mesh region; an elaboration a physical prototype by 3D printing; a technical realization of gear drive by 3D printing. The application of the 3 D technology gives a certain impetus in development of the innovation in the creation of spatial gears. The result is shortening of the cycle of the gear's realization; an elimination of teeth generation errors; a sharp increase of accuracy in gears manufacture and etc. In the study solutions of some of the tasks included in the 3D technology for the creation of the physical prototypes of two class skew-axes gears of type Spiroid and Helicon are illustrated. These gears are dedicated for incorporation into the drive of the fingers of the robot-hand.

■ TB-06

Tuesday, 10:30-12:00 - TIC Lecture Theatre, Level 1

POM Applications IV

Stream: Production and Operations Management
Invited session
Chair: *John J. Kanet*

1 - Trading off inventory, capacity, tardiness, and planned lead time in JIT manufacturing
John J. Kanet

The generally-accepted view of JIT and Lean are that they represent management approaches whose central theme is the elimination of waste, where waste includes all non-value-adding activities/procedures. Per Hopp and Spearman (2004), aside from inventory, waste arises in other forms – namely in excessive capacity or uncompetitive planned lead times and that there exist tradeoffs in terms of inventory, capacity, planned lead time, and customer service. To date there has been no comprehensive approach for modeling these tradeoffs. Defined here is a basic model for JIT manufacturing and a solution procedure for resolving the inventory, tardiness, capacity, and planned lead time tradeoffs.

2 - Joint Order Fulfillment and Inventory Optimization in Generalized W Assemble-to-Order Systems
Man Yu, Jiguang Chen, Shaohui Zheng

This paper characterizes joint order fulfillment and inventory policies for generalized W assemble-to-order systems, where k products are assembled from a common component and k product-specific components. We prove that a nested fulfillment policy, where orders are fulfilled in the decreasing order of selling prices, is optimal for two-product systems. For systems with more than two products, we show that a nested policy may be sub-optimal, but it is asymptotically optimal. Under an optimal fulfillment policy, we further characterize the optimal initial inventory decision.

3 - Additive manufacturing versus MRP & JIT philosophies?
Maria Mavri

Additive manufacturing or 3D printing are two terminologies that refer to a technological procedure that turns computer digital files into solid objects. These solid objects are first designed using a computer and computer-aided design (CAD) software, or the designs are scanned through a 3D scanner, and they are fabricated using a 3D printer. Once the model is created, it is sliced into many cross-sectional layers and a 3D printer can print all the layers and place one on top of the other.

Since 1970, two philosophies have monopolised the production scheme: materials requirement planning (MRP) and just in time (JIT) systems. As is already known, the heart of MRP is the production plan. This plan specifies the number of each item, the exact timing of the production lot sizes, and the final schedule of the competition. The JIT philosophy is used for production lots of small sizes, and it is used in order to ensure that products are produced only as they are needed.

Although it is risky, in this study we assume that production using 3D printers is more familiar with the JIT philosophy than the MRP

philosophy. The goal of this paper is to examine the transformation of the "classic" production procedure, which has many steps and sub-procedures, and to estimate the changes of costs, which are related to manufacture procedure.

■ TB-07

Tuesday, 10:30-12:00 - TIC Conference Room 1, Level 3

Energy Storage and Renewables

Stream: Stochastic Models in Renewably Generated Electricity
Invited session
Chair: *John Boland*

1 - Market impacts of energy storage in a transmission-constrained power system
Vilma Virasjoki, Paula Rocha, Afzal Siddiqui, Ahti Salo

In the last decade, environmental concerns have motivated governments in the European Union and elsewhere to aspire to ambitious targets for generation from renewable energy (RE) technologies by offering subsidies for their adoption and by providing priority grid access. However, because many RE technologies like solar and wind power are intermittent, their penetration places greater strain on the existing transmission capacity and on the ramping of conventional power plants. In this context, energy storage technologies, such as pumped hydro storage or compressed air storage, may offset the intermittency of RE technologies and facilitate their integration into the grid. In order to assess the economic and environmental consequences of storage, we analyze a stylized Western European power system by building a complementarity-based model which features market power, represents the transmission grid, and captures uncertainty in RE output. We show that although storage helps to reduce network congestion and ramping costs in the presence of RE technologies, it may increase CO_2 emissions from conventional power plants due to efficiency losses of storage technologies and a change in generation mix. Insights from our research can be used, for example, to support the decision-making processes of policymakers.

2 - Dispatch optimization under uncertainty for a photovoltaic battery storage system
Kilian Geschermann, Oihane Lacunza, Albert Moser

Due to decreasing costs for photovoltaic cells (PV) and increasing end-consumer electricity prices in Germany, "grid-parity' for PV power was reached in 2012. Since then, electricity generation from PV has been cheaper than purchasing electricity from the grid. Hence, self-consumption of electricity from PV is profitable for end-consumers such as private households. Battery storage systems are an option to further increase the self-consumption rate. With future time-variable electricity consumption and PV feed-in tariffs, dispatch optimization for a PV battery storage system (PV-BSS) can increase the profit margin. The challenge is the uncertainty in PV generation and electricity consumption during the planning period. Therefore, a method for dispatch optimization under uncertainty for a PV-BSS is developed. A deterministic linear programming model is combined with a rolling wave approach. In each rolling optimization step, updated information about current measured PV generation and household electricity consumption as well as forecasts for the remaining planning period are used as input data. Furthermore, stochastic linear programming can also be applied in the model using varying forecast scenarios. Simulation results for an exemplary PV-BSS show significant influence of the developed optimization method on the dispatch compared to simple dispatch strategies, which are usually applied today. Also, the profit margin of the PV-BSS can be noticeably increased.

3 - Optimal control of limited thermal storage for a concentrated solar thermal power plant operating in an electricity market
John Boland, Luigi Cirocco, Martin Belusko, Frank Bruno, Peter Pudney

We present the formulation of and results for, an optimal control strategy for the problem of maximising revenue for a Concentrating Solar Thermal (CST) power plant with Thermal Energy Storage (TES) operating in the electrical National Energy Market (NEM) of Australia

using both a Linear Programming method and the analytical method of Pontryagins Maximum Principle for both infinite or unconstrained storage size and then for the finite or constrained storage problem.

The two methods were used to demonstrate that the optimal revenue results are the same with the analytical approach giving additional insight into the structure of the solution.

From the unlimited or unconstrained storage form of the problem the structure of the optimal operating strategy has three distinct control modes: (i) store all collected power, with no generation, (ii) generate using collected power only, (iii) generate at maximum capacity using both collected and stored power. The mode to be used depends solely on the spot price relative to a pair of critical prices which are related by the turnaround efficiency of the storage system.

We then present the refinement of the optimal strategy from only considering constraints on the controls to placing state space constraints in limiting the storage size.

■ TB-08

Tuesday, 10:30-12:00 - TIC Conference Room 2, Level 3

MAI: Put your agents onto maps: agent-based modelling in geospatial environments

Stream: Making An Impact 1 (MAI 1)
Invited session
Chair: *Benjamin Schumann*

1 - Put your agents onto maps: agent-based modelling in geospatial environments
Benjamin Schumann

Do you like beautiful maps? After all, they provide a huge amount of information visually without overloading our limited information processing capabilities. And how about agent-based modelling for your OR problem? It is a useful alternative for solving many OR problems by defining individual behaviour. The problem is that these two worlds rarely meet. They will in this workshop... Often, OR problems require agents to act in a geospatial environment: Where do you place water reservoirs? What airport destinations are best suited for an airline? How do people use road networks? To date, most people either completely neglected combining Agents and geospatial analysis , or resorted to drawing maps manually. Why is that? Quite simply, both agent-based modelling and geospatial analysis tools are rather sophisticated. Mastering both is a challenge. In this workshop, you will get to see the future of agents and geospatial modelling: We will give you a feel for what it feels like to be an agent on a map. Then, you will send taxi drivers through the maze of central London. You will create a network of pharmacies in one click and get delivery trucks to serve them. You will see agents actually following Google Maps routes (or OpenStreetMap, if you prefer)! And you will learn about other cool capabilities of agents in spatial environments that were fiendishly difficult to do until ... now!

Bring your laptop and you can try the software.

■ TB-09

Tuesday, 10:30-12:00 - TIC Conference Room 3, Level 3

MAI: OR consultancy: art or science?

Stream: Making An Impact 3 (MAI 3)
Invited session
Chair: *Gregor Brandt*

1 - O.R. Consultancy: art or science?
Gregor Brandt

Are you a student or academic thinking about making the switch to full-time practice? Or somebody involved in educating students? This workshop will explore the differences between the academic world and the "real" world, and if you're thinking about switching, help give you a better feeling about your chances of success.

OR is an abstract topic in itself, however, when applied in practice there is a lot of subjectivity coming into play. Surprisingly (or not), gut

feeling and some experience may shorten the duration of any applied OR project drastically, which is important since most of the times, time to come up with a solution that works in practice is limited.

In the workshop, after a short introduction on the OR consultancy context, we will discuss several real life examples with the group. Examples of challenging issues that will be addressed during the workshop are: - Why do universities not deliver reality-ready consultants? - Why would I want to be a consultant anyway? - Is an OR consultant more an artist or a scientist?

■ TB-12

Tuesday, 10:30-12:00 - TIC Conference Room 4&5, Level 3

Mathematical Optimization of Water Networks

Stream: Long Term Planning in Energy, Environment and Climate
Invited session
Chair: *Sophie Demassey*
Chair: *Gratien Bonvin*

1 - Crisis of Water Supply in Jordan
Souhaila Saeed

Keywords : Water shortages, Jordan, leading water supply and demand, sustainable water solutions. Abstract: This paper presents the scarcity of water shortages, the main reason for the severe water shortage in Jordan is simply the lack of natural surface water resources: rivers and lakes.. Definitely, water is the significant feature of water resources in Jordan are limited and the country's population has continued to rise. A high rate of natural population growth, combined with massive influxes of refugees, has transformed into an imbalance condition between population and water. Jordan's water resources are limited to support population in a sustainable manner. The situation has been intensified by the fact that Jordan shares most of its surface water resources with neighboring countries; their control on water has partially disallowed Jordan of its fair share of water. Current use of water already exceeds its renewable supply. The deficit is covered by the unsustainable practice of overdrawing highland aquifers, resulting in lowered water tables and declining water quality. This paper focuses on the water shortage in Jordan, the primarily evaluation of this problem and the solution is contemplate. A true foundation of sustainable water solution requires awareness upon the part of the population, and a number of governmental and non-governmental organizations are actively involved in educating the populace about water shortage. In this research we discussed

2 - Total-factor Water Congestion Efficiency of Regions in China
Jin-Li Hu

This study first measures the water congestion efficiency of 30 regions in China during 2003 to 2012 by the data envelopment analysis (DEA) approach of Tone and Sahoo (2004). We then use the Tobit regression to estimate the effects of three industry classification on the water's efficiency. The results show that 23 out of 30 regions face a congestion situation and the primary industry is the most serious factor that causes water input congestion. For all water use, water efficiency of consumption water is better than ecological protection water and the follow-up is industry water. The agriculture water has most serious input congestion. China should emphasize water savings and industrial restructuring in order to improve its water efficiency.

3 - Short-term power production planning under uncertainty
Michael Burkhardt

Short-term power production planning is done by energy companies to determine a profit maximizing operation schedule meeting several operational boundaries. The production plan is mainly influenced by market prices. For hydro power plants, providing control reserve, it is also important to take into account the activation of control reserve during the planning period. This is because of the limited amount of energy being stored in the water reservoirs. These factors are uncertain during the planning process. This paper aims to consider uncertainty for the short-term operational planning period. It provides a stochastic

programming model formulation to consider the uncertainty in control reserve activation and intraday market prices. The model uses scenario trees as approximations of the activated control energy and the intraday market prices. The model solution is than compared with a deterministic model which does not consider uncertainty. A sensitivity analysis is used to evaluate the dependency on the input data. Results are presented based on a case study for a single pumped storage hydro power plant.

4 - Energy efficiency in water supply systems : variable speed drives vs pumping scheduling
Gratien Bonvin, Sophie Demassey

Improving the energy efficiency is one of the most cost-effective ways to counterbalance the increase of energy costs. In water supply systems, which consume 2-3% of the worldwide energy, energy efficiency is an important subject as energy represents a large amount of operating costs.

Several solutions have been proposed in order to reduce energy costs. In addition to leakages reduction through pressure modulation and network design improvement, two approaches are suggested: - variable speed drive installation, in order to enable pumps maintaining fixed pressure under changing flow conditions, - pumping scheduling, which allows to take advantage from dynamic pricing and to reduce pressure losses.

We estimate the potential energy saves arising from the establishment of these two solutions on a branched network containing a pumping station with 6 fixed speed pumps which supply 16 water towers. We show that installing variable speed drives can lead to a higher energy cost reduction on the short-term but pumping scheduling is a more cost-effective solution after the resizing of the pumping station.

■ TB-15

Tuesday, 10:30-12:00 - TIC Conference Room 6&7, Level 3

Cutting and Packing 6

Stream: Cutting and Packing
Invited session
Chair: *José Fernando Gonçalves*

1 - GRASP for the Rectangular Two-Dimensional Cutting Stock Problem with Usable Leftovers
Óscar Oliveira, Dorabela Gamboa, Pedro Fernandes

We propose an algorithm for the Rectangular Two-dimensional Cutting Stock Problem with Usable Leftovers. In this problem the waste part of a pattern (trim loss) can return to stock and be used in following cutting plans, classifying the resulting object as retail. Objects never submitted to the cutting process are considered standard objects and have unlimited stock. The problem has two additional restrictions: a cut over a rectangular object must produce two new rectangles (guillotine cut); and the cuts must be performed in a sequence of at most k stages of cuts (k-staged). The goal is the minimization of trim loss, number of patterns, number of standard objects used and number of retails in stock, and the maximization of the retails used. Our algorithm is based on the Greedy Randomized Adaptive Search Procedure (GRASP) that creates solutions using a partially randomized greedy procedure in the first phase and then tries to improve them with a Local Search method. In our algorithm, the improvement phase applies a Tabu Search method to all generated solutions that uses three neighborhood structures: 1) Merge Patterns: attempts to create a new pattern joining two existing patterns, 2) Swap Items: exchanges the assignment of two items between patterns and 3) Shift Item: an item is transferred to another pattern. To assess the performance of our algorithm multi-period instances were generated. The GRASP algorithm obtained high quality results in reduced running times.

2 - Efficient Management of Heterogeneous Helicopter Fleets
Carlos Lamas-Fernandez, Julia Bennell, Antonio Martinez Sykora

When managing a helicopter fleet, it is an important strategic decision to determine its ideal size and mix to meet future operations. Critical to this decision is understanding the number of helicopters needed for the transportation of different collections of cargo and the tradeoff between load and flight range for these scenarios. Solving the helicopter loading problem as a one dimensional bin packing problem can support this decision process.

In this work, we present an integer programming model and a genetic algorithm to find efficient placements of items and passengers with three constraints (weight, seats and hooks) in an fleet consisting in helicopters of one or two different types, and aim to minimise the required number of helicopters of each type while considering the maximum range where the fleet can operate.

3 - A Random-Key Genetic Algorithm for Printing Problems
Arnaud Vandaele, Daniel Tuyttens

Printing problems are combinatorial optimization problems and can be considered as a variation of the famous Cutting Stock Problem. They are present in various forms in the literature and they are known by different names (e.g. cover printing problem, label priting problem).

The basic problem is the following: we have a set of books for which it is necessary to produce the covers and the given required number of covers can be different for each book. This problem arises in printing factories and to satisfy the demands, several templates are used. A template can be considered as a large plate on which it is possible to stick different covers. Each template is then copied a number of times in order to meet the demands of covers for each book. The cost of using a template is much more higher than making a copy of it.

The variables of the problem are: the number of templates to use, the number of copies of each of them and the covers configuration on these templates. The objective is to minimize the total cost while producing the required number of copies of each cover. Some very special cases of this problem can be polynomially solved, but in general this problem is strongly NP-Hard.

In the first part of this work we present the different versions of the problem and gather them with the same modelization. We then propose a random-key genetic algorithm in order to process these problems. The results obtained show that the method presented outperforms other algorithms.

4 - A BRKGA for the Unequal Area Facility Layout Problem
José Fernando Gonçalves

Abstract: This paper presents a biased random key genetic algorithm (BRKGA) for the unequal area facility layout problem (UA-FLP) where a set of rectangular facilities with given area requirements has to be placed, without overlapping, on a rectangular floor space. The objective is to find the location and the dimensions of the facilities such that the sum of the weighted distances between the centroids of the facilities is minimized. A novel hybrid approach combining a BRKGA, to determine the order of placement and the dimensions of each facility, a novel placement strategy, to position each facility, and a linear programming model, to fine-tune the solutions, is developed. The proposed approach is tested on 100 random datasets and 28 of benchmark datasets taken from the literature and compared against 21 other benchmark approaches. The quality of the approach was validated by the improvement of the best known solutions for 19 of the 28 extensively studied benchmark datasets. This research was supported by project PTDC/EGE-GES/117692/2010 funded by the ERDF through the Programme COMPETE and by the Portuguese Government through FCT - Foundation for Science and Technology.

◼ TB-16
Tuesday, 10:30-12:00 - TIC Conference Room 8, Level 3

Complexity Analysis and Resolution of Lot Sizing Problems

Stream: Lot Sizing, Lot Scheduling and Related Problems
Invited session
Chair: *Ayse Akbalik*
Chair: *Mahdi Doostmohammadi*

1 - Valid Inequalities for economic lot-sizing problems with remanufacturing: separate setups case
Sharifah Aishah Syed Ali, Mahdi Doostmohammadi, Kerem Akartunali, Robert Van der Meer

In this talk, we investigate the polyhedral structure of a mixed integer set arising from the feasible set of economic lot-sizing problems with remanufacturing and separate setups. First, we study the basic properties and present some general results about trivial facet-defining inequalities. Then, we generate two relaxations of this mixed integer set and study their polyhedral structures. Next, we derive new families of valid inequalities for our mixed integer set and establish facet-defining conditions. We conclude with preliminary computational results to test the effectiveness of these inequalities.

2 - An exact algorithm for lot sizing problem with remanufacturing option with special cost structures
Ashwin Arulselvan, Kerem Akartunali

We study the single item economic lot sizing problem with remanufacturing option, in which we are given an option to produce or remanufacture products over a planning period to satisfy the demand entirely at every time step. The problem was shown to be NP-hard in the literature. We show that there is no FPTAS for this problem and provide a pseudopolynomial time algorithm to solve the problem. We later show how this could be used as an ingredient to construct algorithms for special cost structures.

3 - Valid Inequalities for Two-Period Relaxations of Big-Bucket Lot-Sizing Problems
Kerem Akartunali, Mahdi Doostmohammadi

Although many researchers have studied big-bucket lot-sizing problems, they are still difficult to solve to optimality. In previous research different relaxations such as single-item and single-period have been investigated. We study, in particular the polyhedral structure of mixed integer sets related to various two-period relaxations for big-bucket lot-sizing problems without and with setup times. We derive several families of valid inequalities and investigate their facet-defining conditions and the separation problems associated with them. Finally we investigate the computational strength of these cuts when they are included in an efficient branch-and-cut framework to reduce the integrality gap of the big-bucket lot-sizing problems.

4 - Efficient algorithms and complexity analysis for the lot sizing problem under capacity reservation contract
Ayse Akbalik, Atidel B. Hadj-Alouane, Nathalie Sauer

We consider a manufacturer being replenished by a supplier by batch deliveries under an agreed capacity reservation contract. This contract typically ensures more advantageous price for the manufacturer if the quantity ordered is below a certain capacity reserved at supplier level. However, for each batch exceeding this limit a higher cost is incurred. Hence the procurement cost function of the manufacturer has a non-regular stepwise pattern. As far as we know, this problem has not yet been studied in the literature for batch delivery and single-item case together. We show four variants of this problem to be NP-hard and we propose a pseudo-polynomial time dynamic programming algorithm for the general case. The general problem is thus NP-hard in the ordinary sense under arbitrary parameters. We also propose trivial and non-trivial polynomial time algorithms under different assumptions on the cost and capacity functions.

◼ TB-17
Tuesday, 10:30-12:00 - TIC Conference Room A, Level 9

IBM Research Applications

Stream: IBM Research Applications
Invited session
Chair: *Odellia Boni*
Chair: *Martin Mevissen*
Chair: *Marco Laumanns*

1 - A Fair Assignment of Shared Cars to Parking Lots
Nicole Taheri, Jia Yuan Yu, Robert Shorten

With increasing concern for environmental issues, sharing vehicles among a community of drivers may be a practical solution to reducing the environmental impact of standard vehicles. In such a setting, the shared vehicles could be picked up and dropped off at specified parking lots. In order to avoid over-crowding of specific lots, the drivers

may be requested to park their vehicles in a parking lot that is not closest to their destination. We propose a method to assign parking lots to drivers, given their starting and ending destinations and times. Inspired by work on car park design by Griggs et al., our method maximizes the fairness of the assignments among drivers. To do this we solve a centralized mixed-integer linear program to provide a destination lot assignment to each vehicle over a series of days, and report our results using different objectives for fairness.

2 - Sequential human choice modeling
Takayuki Osogami

We seek to model what a person is going to choose when multiple alternatives are given. A typical application is in understanding the services or products that a customer wants to purchase. Human choice can be learned by observing the choices from varying choice sets, but the effectiveness of this learning depends on the choice sets which choices are made from. The choice from some choice sets might directly give information about the choice model, but the amount of the information might be limited. The choice from other choice sets might allow us to infer what choice sets will give a large amount of information. We optimize the choice sets via partially observable Markov decision process when a person make choices multiple times. We also deal with the typical phenomena of human choice, including the attraction effect and the compromise effect, that make human choice modeling particularly difficult. A part of this research was supported by CREST, JST.

3 - Using CP for VLSI Rectangle Placement
Odellia Boni

We report our solution to the problem of designing test-site chips. This is a specific variation of the VLSI floorplanning problem where rectangular macros must be placed without overlap in a given area, but no wiring between the macros exists. Typically, industrial problems of this type require placing hundreds of macros of different sizes and shapes and include additional constraints such as fixing or grouping some of the macros. We used constraint programming (CP) with additional heuristics, including sophisticated variable and value orderings, to produce floorplans for real test-sites. Our CP solution is successfully used in production by test-site designers.

■ TB-18
Tuesday, 10:30-12:00 - TIC Conference Room B, Level 9

Energy Market Modeling 3: Risk and Reliability in Transmission Network Operation and Planning

Stream: Energy Market/System Modeling
Invited session
Chair: *Waqquas Bukhsh*

1 - Measurement of risk on large power systems
Tim Bedford, Keith Bell, Waqquas Bukhsh

Low carbon energy generation and liberalisation are forcing fundamental changes to the electricity network and incentivizing 'smarter' operation. Optimal investment modelling is subject to technical, performance and competition constraints on allowable options. A better understanding of these constraints could allow for the relaxation of historic conservative constraints such as the N-1 design and operation criterion for networks (which essentially says that the grid must be capable of operation within normal limits when it loses one piece of major infrastructure). In principle we can do this through use of risk based performance measures. We consider the definition of risk measures that provide summaries of overall system performance as guidance for system planners and operators. High level measures such as Value of Lost Load exist and are influenced by a variety of factors. System operators and designers can only influence these factors through the decisions they make, and therefore we need to construct intermediate risk measures that provide a link between higher level measures such as VOLL on the one hand, and those issues that are influenced by system operator and designer decisions on the other, taking account of the above issues of planning horizon, network topology and control. We shall discuss potential ways forward, making comparisons to risk measures adopted in other industries. This research is supported by the GARPUR FP7 project, GA 608540.

2 - From responsibility to accountability: Electricity market mechanisms accomodating probabilistic offers
Athanasios Papakonstantinou, Pierre Pinson

Large scale integration of stochastic renewable sources of energy (mainly wind and solar power) over the recent years has brought important economic and environmental benefits with many countries adopting favorable regulatory frameworks to further promote their development. Such sources of energy are usually non-dispatchable and partly predictable, so support mechanisms were put in place in order to safeguard stochastic producers against price volatility. However, as their stakes increase, electricity markets over-relying on support mechanisms also increase losses in social welfare by transferring imbalance costs to consumers. This calls for a new approach in the design of electricity markets whereby those responsible for imbalances are also accountable. In this paper, we propose a shift from the current paradigm of treating stochastic producers similarly to the conventional ones. We argue that the producers' offers should be probabilistic, instead of deterministic, so that they reflect the stochastic nature of production and design a market mechanism to accommodate such offers. The mechanism allocates uncertainty risk proportionally to the stochastic producers, while we analytically prove that revenues are equal to a linear transformation of a strictly proper scoring rule. This shows that the mechanism elicits accurate and precise forecasts. Finally, a Monte Carlo simulation of the clearing of a simple power system serves as an illustrative example and proof of concept.

3 - Probabilistic criteria for power system reliability management
Efthymios Karangelos, Louis Wehenkel

This work investigates the formulation of probabilistic reliability criteria for reliability management in the context of real-time operation. In real-time operation reliability management, the aim is to arbitrate in a rational way between preventive and corrective control while maintaining system functionality. As the current reliability management approach based on the deterministic N-1 criterion is challenged by the growth of uncertainties, we propose to explicitly acknowledge (i) the prior probabilities of contingencies, (ii) the possible failure modes of corrective control actions, and, (iii) the socio-economic consequences of service interruptions. Noting the spatio-temporal variability in all three aforementioned factors, we argue for reliability criteria assuring the probability of avoiding service interruptions of severe consequences. Accordingly, we formalize the real-time reliability management decision making problem in the framework of chance-constrained stochastic optimization. This work is a first step towards the construction of a globally coherent decision making framework for reliability management from long-term system expansion, via mid-term asset management, towards short-term operation planning and real-time operation.

■ TB-25
Tuesday, 10:30-12:00 - John Anderson JA3.14 Lecture Theatre

Environmental Sustainability in Production and Sourcing

Stream: Environmental Sustainability in Supply Chains
Invited session
Chair: *Emel Arikan*

1 - The State of Scope 3 Carbon Emissions Reporting in Supply Chains
Charles Corbett, Christian Blanco, Felipe Caro

For most firms, the main opportunities for reducing carbon footprint lie upstream in their supply chain. We use CDP (formerly Carbon Disclosure Project) data on Scope 3 emissions (those embedded in products and services purchased) for 374 US firms to assess to what extent they measure their supply chain carbon footprint. We use the breakdown of emissions into Scope 1, 2 and 3 from Huang et al. (2009) as a benchmark, and estimate that firms who disclose to CDP currently under-report Scope 3 emissions by 492 million tonnes of CO_2-e, 60% of their total estimated Scope 3 emissions.

2 - Inventory pooling with environmental constraint using copulas

Werner Jammernegg, Peter Kischka, Lena Silbermayr

We consider different inventory pooling models (e.g. transshipment) within the newsvendor framework. At first glance the distribution system with pooled demand leads to higher expected profit but it also results in higher product carbon footprint(expected emissions from production,leftovers and transportation). The focus of the paper is on the dependency of the demand distributions described by the copula of the joint demand. Especially, for symmetric and skewed beta-distributed demands selected copulas are analyzed.

3 - Integrating dual sourcing and recycling options for critical materials

Patricia Rogetzer

Companies are increasingly faced by securing a steady stream of supply of raw materials for their production. A mounting shortage of resources as well as volatile raw material prices (commodity prices and availability risks) make it extremely difficult to secure a stable supply of production inputs to the supply chain. These challenges can be mitigated by closing the loop of forward and reverse supply chains, i.e. considering flows of new and returned products simultaneously. Since the use of recycled materials is of increasing importance in modern production economies from an economic, ecological and social point of view, the integration of these inputs in existing production systems is of utmost importance. The use of secondary materials, though, is challenging due to the fact that product return rates are highly volatile (demand and yield uncertainty). Options for sustainable actions with respect to the efficient and effective recycling of secondary raw materials are shown. In this talk, an overview of the application of dual sourcing strategies in the context of supply chain management as well as other possibilities for substitution on the component and/or material level are proposed depending on an up-to-date review of academic and practitioner literature on supply chain strategies and practices for integrating dual sourcing and recycling options.

4 - Analysis of a dual sourcing inventory model with carbon emissions constraint

Emel Arikan, Johannes Fichtinger

Measuring and reporting carbon emissions has becoming the rule rather than the exception in several industries. A considerable number of companies publicly state their carbon emission reduction targets. In this study, we consider an inventory system under a carbon emission reduction target. Specifically, we analyze a multi-period dual sourcing inventory model with a constraint on emissions resulting from sourcing and warehousing. We analyze the optimal order quantities under the dual index policy with a carbon constraint. Since the emissions resulting from transportation and warehousing are random we define two different types of constraints. The first one is a constraint on the expected emissions per period and the second one is an upper limit on the probability of exceeding a target emission level. We present the impact of such an environmental criterion on the optimal allocation between the offshore and onshore suppliers and provide sensitivity results based on a numerical study.

■ TB-26

Tuesday, 10:30-12:00 - John Anderson JA3.17 Lecture Theatre

Stochastic Models in Manufacturing and Logistics I

Stream: Stochastic Modeling
Invited session
Chair: *Axel Franz*

1 - Performance Approximation of Drop & Swap Operations in On-site Logistics

Axel Franz, Jan C. Fransoo, Raik Stolletz, Maximiliano Udenio

In the chemical industry, road and intermodal transportation of bulk liquids and gases is performed with dedicated tank containers or tank trailers. The corresponding loading operations at the chemical plant face time-dependent and stochastic truck arrivals, causing long waiting times during peak hours.

Implementing drop & swap operations is an approach to increase capacity and improve performance, and safety, by decoupling the tank loading operations from the truck loading operations. A purpose-built parking area outside the plant is constructed and provided with appropriate equipment for container or chassis exchange. Trucks from external origins deliver empty and clean tanks and pick up full ones directly in this drop & swap area. Additionally, dedicated trucks are operated to internally transport the empty tanks from the drop & swap area to the loading station and from there back to the drop & swap area.

We formulate a mixed queueing network model of the related system and analytically assess the potential of drop & swap operations on the steady-state performance compared to the conventional direct loading operations. Furthermore, we propose a decomposition-based approximation approach to evaluate the system's time-dependent performance.

2 - Optimizing Arrival Patterns in Time-dependent Queues

Raik Stolletz, Axel Franz

Demand management mechanisms for distribution centers aim at smoothing demand by shifting truck arrivals from peak to off-peak periods in order to improve the system's operational performance. We provide a general, reliable, and fast methodology to evaluate and optimize the arrival pattern for the time-dependent G(t)/G/c queueing system of truck handling operations.

Our optimization approach is based on the stationary backlog-carryover approach to analyze the system's performance. The time-dependent arrival rates serve as decision variables, i.e., the decision model's outcome are changes to an originally preferred or forecasted demand pattern. Two objectives are considered in this non-linear optimization model: Minimizing total waiting times and minimizing the related and penalized shift in the arrival pattern. A numerical study compares the performance measures of original and optimized arrival patterns for truck handling operations of a distribution center and at an air cargo terminal. It shows that a significant reduction in waiting times can be reached even with minor shifts in time-dependent arrival rates.

3 - Strategic Behavior of Heterogeneous Customers in a Transportation Station

Athanasia Manou, Fikri Karaesmen, Pelin Canbolat

We consider a transportation station, where customers arrive according to a Poisson process. A transportation facility with unlimited capacity visits the station according to a renewal process and at each visit it serves all present customers. We assume that the arriving customers are free to decide whether to join or balk based on a natural cost-reward structure, which is imposed on the system and reflects their desire for service and their unwillingness to wait. Moreover, each customer has a delay-sensitivity parameter that indicates his importance of time. The delay-sensitivity parameters of the successive customers are independent and identically distributed random variables. We determine the equilibrium behavior of the customers in three different cases depending on the information that customers receive at their arrival instants. Specifically, we study the unobservable, the partially observable (the queue length is observed) and the observable case(the exact waiting time is observed). Then, comparing the three levels of information we conclude which level is preferable for the customers, for the service provider and for the society.

■ TB-27

Tuesday, 10:30-12:00 - John Anderson JA3.27, Level 3

Planning and Scheduling Approaches for Complex Manufacturing and Service Systems

Stream: Scheduling, Sequencing, and Applications
Invited session
Chair: *Lars Moench*

1 - A Hybrid Approach to Optimize Mixed Model Assembly Lines

Alexander Biele, Lars Moench

We discuss an optimization problem for mixed model assembly lines in low-volume manufacturing as found in the aerospace industry. A novel time-indexed formulation to allocate workers to jobs and stations and to compute start and completion times of jobs on stations is proposed. It uses a linear objective function that balances the total inventory and the labor costs of an assembly line assuming a given sequence of jobs. Small-sized problem instances can be solved by a commercial solver, whereas a hybrid approach is designed to solve large-sized problem instances in a reasonable amount of time. Therefore, we hybridize Variable Neighborhood Search (VNS) with Mixed Integer Programming. The VNS approach is applied to determine start and end dates for jobs on stations. Each single shaking step of the VNS approach requires the solution of a Mixed Integer Program to determine the number of workers per job and station in a period. We propose appropriate neighborhood structures for the VNS approach. Results of extensive computational experiments based on randomly generated problem instances and on a few real-world like instances from a real assembly line are presented. The results demonstrate that the proposed method outperforms a solution approach from the literature. Moreover, we also prove that it is likely that the hybrid approach will be beneficial for industrial applications.

2 - A MIP-formulation for Energy-aware Scheduling with Variable Discrete Production Rates

Udo Buscher, Sven Schulz

This paper introduces a MIP-formulation for energy-aware hybrid flow shop scheduling. In contrast to the large majority of scheduling-papers, a cost-oriented approach is chosen. The objective is to minimize the sum of production, energy, and lateness cost. In addition to the processing order of the jobs, the proposed scheduling problem considers variable discrete production rates to affect peak load and energy consumption. Since electricity prices may vary with the time of the day, so-called time-of-use prices are considered to exploit energy price fluctuations. Due to the complexity of the problem, applying commercial software requires significant computation time. Nevertheless, the new model is illustrated with small numerical examples.

3 - Scheduling Fixed Position Maintenance Operations

Florian Jaehn, Maciej Drozdowski, Radoslaw Paszkowski

In this presentation scheduling with fixed sequence positioning of maintenance operations is considered. A maintenance operation has a fixed position in a sequence of normal jobs if the maintenance has to be performed after at most some defined number of job changes on the machine. A problem of preemptive scheduling with ready times and due-dates on one machine is considered. We show that this problem is computationally hard in general. Special cases of scheduling for with C_max criterion or for L_max criterion with equal ready times are polynomially solvable. After determining a set of dominance properties a branch and bound algorithm using local search for upper bounds is proposed.

4 - Parallel Machine Scheduling with Qualification and Secondary Resource Constraints

Lars Moench, Claude Yugma

In this paper, we consider a scheduling problem for identical parallel machines where the jobs belong to different families and have unequal release dates. This problem is motivated by process conditions found in the photolithography work area of semiconductor wafer fabrication facilities. A job can only be processed on a machine if a secondary resource, a reticle, is available. A machine has to be qualified for a certain family. A qualification is only valid for a certain time window that depends on the family. The qualification can be preserved by running jobs of this family within this time window. Machines can be requalified for a certain family using so-called send-ahead wafers. We consider a combined criterion that includes the makespan and the number of send-ahead wafers. A mixed integer linear programming (MILP) formulation is derived. We propose a list-scheduling heuristic. Computational experiments for randomly generated problem instances are carried out.

■ TB-28

Tuesday, 10:30-12:00 - John Anderson JA3.26, Level 3

Nurse rostering

Stream: Timetabling
Invited session
Chair: *Greet Vanden Berghe*

1 - MIP-Based Variable Neighborhood Search Algorithm For Solving Nurse Scheduling Problems

Erfan Rahimian, Kerem Akartunali, John Levine

Nurse Scheduling aims to assign a number of nursing staff to several shift types (e.g. early, late, and etc.) during a planning period satisfying some requirements and preferences. During the last decade, this problem has drawn significant interest and a wide body of research in the relevant literature is accomplished with a diverse variety of solution methods such as Integer Programming techniques and Heuristics to solve it efficiently. In this paper, we propose a hybrid Variable Neighborhood Search (VNS) algorithm which calls a Mixed Integer Programming (MIP) solver iteratively. First, an initial feasible solution is generated using a greedy heuristic, which is then improved by a Variable Neighborhood Descent (VND) algorithm used as a local search, until predefined stopping criteria are met. Furthermore, in each iteration, the generated solution is further improved using an MIP solver by fixing the least penalized part of the solution during a predefined time. In order to diversify the search process, some high penalized parts of the solution are also fixed randomly. To evaluate the efficiency of the proposed algorithm, we test it by 20 instances from the recent literature. The results show that our algorithm outperforms the current best algorithm and the state-of-the-art MIP solvers for most of the instances.

2 - Staff well-being in rostering

Jane Parkin, Sanja Petrovic

Research methods for rostering consider a variety of real-world constraints, while some also attempt to accommodate employee preferences. However, although there has been increasing interest in the idea of "well-being', and evidence that improving staff well-being improves organisational outcomes, rostering methods tend not to consider this in any formal or objective way, apart from complying with rules such as the EU working time directive. Our research aim is to incorporate findings of occupational medicine on well-being of staff working shifts into OR rostering methods. An overview of well-being literature is given followed by discussion about aspects of well-being we suggest for roster evaluation. These include work-life balance measures, deviations from Health and Safety Executive guidelines, fatigue and risk indicators. We start our research with nurse rostering due to the number of developed methods and availability of problem instances. A real-world nurse rostering problem is chosen for which we have rosters generated both by OR and manual methods. We analyse and compare proposed well-being measures of these rosters. There is no consistent conclusion as to which method results in better well-being. However, none of the methods was designed with well-being in mind. If well-being measures are included in the objective function, it would be feasible to test the effect of giving different weightings to the efficiency and well-being measures on resulting rosters.

3 - Nurse Scheduling Problem: a Model and a Solution for a Real Case

Mustafa Kocabaş, Necati Konyalı, Dilber ÜnlÜ, Elif İlhan

Nurse scheduling is a complex problem with many constraints to be satisfied such as maximum working hours, night and day shifts balance, weekend off days, staff shift and working day preferences, and etc. Optimized schedules can provide enormous benefits, but require carefully implemented decision support systems if an organization is to meet customer demands in a cost effective manner while satisfying requirements such as flexible workplace agreements, shift equity, and staff preferences. In this study we focus on a real case nurse scheduling problem from the literature. The hospital that we study on has just two types of shifts, one of them is 13 hour day shift and another one is 12.5 hour night shift. In the article problem is solved with two dimensional genetic algorithm. We proposed a mathematical model and solved the model via a software to find the optimum schedule.

4 - Network flow models for nurse rostering problems
Greet Vanden Berghe, Pieter Smet, Patrick De Causmaecker

Nurse rostering deals with the task of assigning shifts to nurses subject to various legislative and organisational constraints. It is generally assumed that these problems are hard, whereas, actual proofs supporting such statements are rare. This talk concentrates on simple nurse rostering problems, formulated as minimum cost network flow problems. A class of nurse rostering problems is identified which can thus be solved in polynomial time. In light of these new results, complexity results from the academic literature are revisited, thereby allowing to identify a boundary between easy and hard nurse rostering problems.

■ TB-29

Tuesday, 10:30-12:00 - John Anderson JA4.12, Level 4

Early Warning Systems for Nature, Finance and Economy

Stream: Data Mining in Early Warning Systems
Invited session
Chair: *Inci Batmaz*

1 - The Precipitation Modeling of Aegean Region of Turkey with Multivariate Adaptive Regression Splines and Time Series Regression
Ceyda Yazici, Inci Batmaz, Ceylan Yozgatligil

Climate change is one of the major factors affecting the environment and human beings. The increase in the average temperature, the instability in the precipitation regimes, floods, and droughts are some of the consequences of the climate change. In order to eliminate the damage or reduce the effects of these extreme weather events the precipitation amounts should be predicted, thus, the precautions can be taken in advance. Since the early warning systems for the precipitation is needed, the statistical modelling of the meteorological variables may be considered. It is also possible to model the other meteorological variables such as average temperature. As a beginning of the study, a nonparametric model, namely multivariate adaptive regression splines and time series regression is applied. The data used is taken from Aegean region of Turkey from several stations and the precipitation amount is predicted for each station.

2 - Modelling Daily Occurance of Precipitation for Certain Regions of Turkey Using Hidden Markov Models (HMMs)
Inci Batmaz, Nevin Yaman, Ceylan Yozgatligil

Precipitation models play an important role in forecasting climate changes. In this study, we develop models for daily precipitation occurrences of two regions of Turkey using Hidden Markov Models (HMMs). They are the driest and normal moisture climate regions, namely, Continental Anatolia and Aegean Region. Results indicate that HMMs are particularly successful in modeling average moisture daily occurrence data.

3 - Data Envelopment Analysis Associated with Sharp's Approach in Portfolio Optimization
Sebastião Serpa, Pedro Gonçalves, Paulo Rotela Junior, Luiz Celio Souza Rocha, Giancarlo Aquila, Victor E M Valerio, Marcelo Nunes Fonseca

This paper aims to apply Data Envelopment Analysis with the model proposed by Sharpe, to optimize the portfolio of assets of São Paulo Stock Exchange. For that, will be analyzed including new indicators, comparing them to the use of others indicators identified in the literature. The research method used was the mathematical modeling, in which the possible variables to be tested were selected based on literature review. And data were obtained through Economatica database. It was observed that the best portfolio was the one that used volatility as input variable for the three different time periods and analyzed, in turn, the one with the best relationship between return and risk.

4 - An Investigation of Dependence in Expert Judgement Studies with Multiple Experts and Lessons for Forecasting
Kevin Wilson

Expert judgement plays an important role in forecasting and elsewhere as it can be used to quantify models when no data are available and to improve predictions from models when combined with data. In order to provide defensible estimates of unknowns in an analysis the judgements of multiple experts can be elicited. Mathematical aggregation methods can be used to combine these individual judgements into a single judgement for the decision maker. However, most mathematical aggregation methods assume judgements coming from experts that are independent. This is unlikely to be the case in practice. This talk investigates dependence in expert judgement studies, both within and between experts. It considers all of the studies in the TU Delft database. It then assesses the practical significance of the dependencies identified in the studies by comparing the performance of several mathematical aggregation methods with varying dependence assumptions. Between expert correlations are more prevalent than within expert correlations. For studies which contained between expert correlations, models which include this could improve forecasts. The implications for the use of expert judgement in forecasting are discussed.

■ TB-30

Tuesday, 10:30-12:00 - John Anderson JA5.02, Level 5

Simheuristics: Applications and Methodology

Stream: Simulation and Optimization
Invited session
Chair: *Javier Faulin*

1 - Market Segmentation Issues in the Multi-Depot Vehicle Routing Problem
Laura Calvet, Albert Ferrer, Angel A. Juan, Maria Isabel Gomes

A new methodology is proposed to tackle a Multi-Depot Vehicle Routing Problem (MDVRP) dealing with heterogeneous depots, which leads to consider customer preferences. A market segmentation strategy is designed to assign the customers based on their preferences, which may be measured through the predicted expenditure. The main aim is to maximize the expected benefit, computed as the difference between the predicted expenditure and the transportation costs. Our approach involves gathering historical data about old customers which were assigned depending on transportation costs or randomly. Specifically, for each of these customers there is information about demographic features (as age, gender, etc.), geographical location, depot assigned and expenditure. Using this data, Multiple Linear Regression functions are learned, one per depot, and used to predict the expenditure of a new customer if he was assigned to each one of the depots.

2 - Applications of Simheuristics in Transportation and Logistics
Angel A. Juan, Javier Faulin, Laura Calvet, Adela Pages Bernaus, Carlos L. Quintero-Araújo

Many combinatorial optimization problems (COPs) encountered in real-world logistics and transportation applications are NP-hard in nature. These real-life COPs are frequently characterized by their large-scale sizes and the need for obtaining high-quality solutions in short computing times, thus requiring the use of metaheuristic algorithms. Metaheuristics frequently assume that the problem inputs, the underlying objective function, and the set of optimization constraints are deterministic. However, uncertainty is all around us, which often makes deterministic models oversimplified versions of real-life systems. This presentation describes a general methodology that allows for extending metaheuristics through simulation to solve stochastic COPs. 'Simheuristics' allow modelers for dealing with real-life uncertainty in a natural way by integrating simulation into a metaheuristic-driven framework. These optimization-driven algorithms rely on the fact that efficient metaheuristics already exist for the deterministic version of the corresponding COP. Simheuristics also facilitate the introduction of risk and/or reliability analysis criteria during the assessment of alternative high-quality solutions to stochastic COPs.

3 - Biased Randomization of Heuristics for Combinatorial Optimization

Alex Grasas, Javier Faulin, Angel A. Juan, Helena Ramalhinho Lourenco

Many types of heuristics have been developed to solve combinatorial optimization problems. Heuristics use iterative processes to find better solutions. At each iteration, the next constructive movement is selected from a list of potential candidates that has been sorted according to some criteria. If the next best movement is always selected, the procedure could be seen as deterministic and iterative greedy. In order to obtain different outputs and, therefore, explore other solutions, randomization is employed to select next movements from the list. However, if a uniform distribution determines such randomization the logic behind the greedy behavior is faded away. To preserve the better features of the top listed candidates while maintaining the randomized behavior of the procedure, biased randomized algorithms have been proposed in a myriad of contexts. A biased randomized algorithm uses a biased probability distribution (e.g., geometric, triangular) to select the next constructive movement at each iteration. In this paper we present a general framework for biased randomized metaheuristics that includes an extensive review of applications to different problems such as vehicle routing problems, arc routing problems, packing problems, flow shop problems, etc.

4 - Quasi-optimal routing of ambulances: A case study and analysis for Zomba central hospital catchment area

Javier Faulin, Elias Mwakilama

We aim at improving the response time of picking-up and delivering patients to main referral hospital from the scattered health centers in rural areas. Using a modified Dijkstra's algorithm, implemented in Java, minimal travel times under the influence of meandering type of roads are generated, signifying the importance of considering meandering correction factor when determining travel times in rural set up. The study also demonstrates efforts of addressing Rural Postman Problem aspects.

■ TB-31

Tuesday, 10:30-12:00 - John Anderson JA5.04, Level 5

Big Data Analysis 1

Stream: Stochastic Modeling and Simulation in Engineering, Management and Science
Invited session
Chair: *Zeev (Vladimir) Volkovich*
Chair: *Boris Goldengorin*

1 - Proposition of a data format for ubiquitous systems

Malika Yaici

Ubiquitous computing is one of the challenges of actual computer science. One characteristic of these systems is the heterogeneity of its components, which causes problems of communication and interoperability in addition to performance constraints and energy due to the miniaturization. Mobility and dynamic reconfiguration will be the dominant features of these systems, requiring permanent adaptation of applications. One solution is the design of a standard data representation format which consists of a condensation technique to reduce the size of data exchanged between different devices. An application to manage student's access to different services has been implemented for evaluation.

2 - Time series representation and similarity based on local auto-patterns

Mustafa Baydoğan, George Runger

Time series data mining has received much greater interest along with the increase in temporal data sets from different domains such as medicine, finance, multimedia, etc. Representations are important to reduce dimensionality and generate useful similarity measures. High-level representations such as Fourier transforms, wavelets, piecewise polynomial models, etc., were considered previously. Recently, autoregressive kernels were introduced to reflect the similarity of the time

series. We introduce a novel approach to model the dependency structure in time series that generalizes the concept of autoregression to local auto-patterns. Our approach generates a pattern-based representation along with a similarity measure called Learned Pattern Similarity (LPS). A tree-based ensemble-learning strategy that is fast and insensitive to parameter settings is the basis for the approach. This unsupervised approach to represent and measure the similarity between time series generally applies to a number of data mining tasks (e.g., clustering, anomaly detection, classification). We compare LPS to eleven well-known similarity measures. Our experimental results show that LPS provides fast and competitive results on 75 benchmark datasets from several domains. Furthermore, LPS provides a research direction for time series modeling that breaks from the linear dependency models to potentially foster other promising nonlinear approaches.

3 - Sales Forecasting in Fashion Retailing Using Weighted Extreme Learning Machine: From a Perspective of Multi-class Classification

Jingfang Zhu, Hu Qin

Sales forecasting is an important part in establishing a production plan in fashion retailing. Although this area has been widely studied, the literature papers of sales forecasting from the perspective of multi-class classification is scarce. Since the fashionable products have short life cycle and heavily fluctuant selling quantities, it is very difficult to forecast their accurate sales quantities. Instead, we aim to forecast the market trend of such products. From a multi-class classification point of view, according to the selling quantity, the sailing market can be divided into three main parts, namely good, normal and bad, and accordingly the products can be attached three types of labels. For a certain fashionable product in multiple period selling horizon, since the normal selling quantity occurs more frequent than the good or bad selling quantity, forecasting the label type of this product can be viewed as a multi-class imbalanced classification problem, which is more complicated than the traditional classification problem. The method used in this study to deal with this problem is the newly proposed weighted extreme learning machine (WELM), which is an improved version of the extreme learning machine. Based on our numerical experiments and compared with several existing techniques, we demonstrate that the WELM is very suitable to deal with the multi-class classification problems in which the sales quantities of the products involved are imbalanced.

4 - Big Data Compression by Pseudo-Boolean Polynomials

Boris Goldengorin, Michael Tso, John Keane

In this talk we show how to aggregate and compress the numerical data in huge m (rows) times n (columns) tables by means of ordering the entries within their columns in a non-decreasing (non-increasing) order. The ordered columns can be represented by the corresponding permutations and differences between the neighboring entries. Note that equal sub-permutations of ordered columns reflect similar sub-orderings in data columns. Those sub-permutations can be represented by means of the corresponding products of Boolean variables. The related differences will be the coefficients of the returned pseudo-Boolean polynomial. The computational time complexity of creating a pseudo-Boolean polynomial is at most O(nmlogm). The number of compressed data rows can be truncated depending on the nature of requested information and may be fixed to their pre-specified number . Our computational study shows that for complete (dense) transportation type graphs (networks) containing thousands of vertices the number of entries after compression can be reduced by more than 90%. One of our applications in Industrial Engineering can be found in B. Goldengorin, D. Krushinsky, P. M. Pardalos. Cell Formation in Industrial Engineering: Theory, Algorithms and Experiments. Springer, 2013.

■ TB-32

Tuesday, 10:30-12:00 - John Anderson JA5.05, Level 5

AHP/ANP 06

Stream: Analytic Hierarchy/Network Process
Invited session
Chair: *Tihomir Hunjak*

1 - A Model for Product Prioritization based on Effectiveness on Corporations' Interests in the Dairy Industry: A Case Study in Iran

Saeed Saljooghi, Negar Golamian

We are all constantly dealing with multi-purpose and multi-criteria matters in business world. Executives, in manufacturing companies, have to decide between value creating criteria one of which is how to manage and optimize production programs. Right decisions, in effect, help in having high profits and quality products and well-satisfied customers. To avoid irresistible losses and losing customers, we have to try our best to have the right and optimum choice. Practicing the hierarchical decision-making and merging it into arithmetic optimization techniques, we put hard effort into presenting an effective model for prioritization of production plans with maximum profit for dairy corporations. The suggested model was practically exercised and presented as a case study in a dairy producer company in Iran. Accordingly, the company's products can be prioritized based on the effect any product has on productivity, investment, sale market, competitive advantages, transportability, etc. and an optimum monthly daily production plan is set.

2 - Strategic Segmentation of Customer Types by Cluster Analysis

Zongyao Xu, Tingting Zhou, Nanya Rong, Peng Xu, Hong Seung Ko

Customer segmentation must be necessary for making clear the customer who should be retained that brings sales improvement and profits increase to a company. In researches of customer segmentation, there is one paper which strategically analyzes existing customer types by Analytic Hierarchy Process(AHP). However, we consider that cluster analysis is suitable than AHP analysis as the ways of strategic customer segmentation. Therefore, we carry out the strategic customer segmentation by using Cluster Analysis with setting three factors such as purchase amounts, purchase frequency and contribution degree as the evaluation base of customer retention. Finally, we check the validity by comparing the results with AHP results.

3 - Prioritizing Offshore Vendor Selection Criteria for the North American Geospatial Industry

Simon Musaeus

The U.S. market for geospatial services totaled US $2.2 billion in 2010, representing 50% of the global market. Data-processing firms subcontract labor-intensive portions of data services to offshore providers in South and East Asia and Eastern Europe. In general, half of all offshore contracts fail within the first 5 years because one or more parties consider the relationship unsuccessful. Despite the high failure rates, no study has examined the offshore vendor selection process in the geospatial industry. The purpose of this study was to determine the list of key offshore vendor selection criteria and the efficacy of the analytic hierarchy process (AHP) for ranking the criteria that North American geospatial companies consider in the offshore vendor selection process. The results showed that the quality of deliverables was the top ranked (out of 26) factors, instead of the price, which ranked third. Similarly, SMEs considered social and environmental consciousness on the vendor side as irrelevant. More importantly, the findings indicated that the structured AHP process provides a useful and effective methodology whose application may considerably improve the quality of the overall vendor selection process. Last, improved and stabilized business relationships leading to predictable budgets might catalyze social change, supporting stable employment. Consumers could benefit from derivative improvements in product quality and pricing.

4 - Advantages and Disadvantages of using the AHP Method in Public Procurement

Tihomir Hunjak, Zoran Babic

There is ample evidence for the claim that AHP method has many advantages over other MCDM methods in solving supplier selection problems. However, in the framework of public procurement rules all these advantages are not usable in full measure. The main reason for this is that the public procurement rules in the supplier selection problem bring additional complexity in which the two main aspects are the legal aspects and the socio-economic aspect. The paper presents results of research on the possibilities and limitations associated with the use of AHP method in public procurement. The results of this research are presented in the form of a SWOT analysis.

■ TB-33

Tuesday, 10:30-12:00 - John Anderson JA5.06, Level 5

Reliability and Maintenance

Stream: OR in Quality Management
Invited session
Chair: *Gul Okudan Kremer*
Chair: *Ipek Deveci Kocakoç*

1 - A model based on cost minimization and reliability enhancement to solve the power plant preventive maintenance scheduling problem

Salvador Perez-Canto

1. Introduction and problem description The Power Plant Preventive Maintenance Scheduling Problem (PPPMSP) requires determining the period for which generating units of an electric power system should be taken offline for planned preventive maintenance over a time horizon. The research performed here encompasses a wide range of power plants: thermal, nuclear, hydroelectric, and wind power plants.

2. Model formulation and methodology The PPPMSP is a complex optimization problem. Objectives such as total cost minimization and consecution of a certain reliability level are proposed by imposing an objective function and satisfying a set of constraints. This problem is categorized as a 0/1 mixed integer linear programming problem. Its resolution involves the use of an optimiser.

3. Application example and findings An example based on a high-dimensioned realistic power system was undertaken to validate the model. The findings demonstrate that the model works correctly.

4. Conclusions a) Several costs are integrated. b) Different power plants were considered. c) A wide variety of constraints is included. d) The results could be useful if they are applied to other realistic cases.

5. References Ben-Daya, M., Duffuaa, S.O., Raouf A. (Eds), (2000). Maintenance, Modeling and Optimization. Kluwer, Boston. Ekpenyong, U.E., Zhang, J., Xia, X. (2012). "An improved robust model for generator maintenance scheduling'. Electric Power Systems Research. 92, 29-36.

2 - An Application of Multiobjective Evolutionary Algorithm to Reliability Optimization

Ipek Deveci Kocakoç, Gokce Baysal, Yasin Büyükkör

Reliability optimization is an important issue for sustainability of competition in industry. Purpose of this paper is to optimize reliability of a system/subsystem data of an electronics company by multiobjective evolutionary algorithm. Reliability, weight, volume and cost functions of this system are used as objective functions and solved by multiobjective evolutionary optimization algorithm. The aim of this optimization is to maximize reliability whereas other functions minimize. In conclusion, effects of changing values of weight, volume and cost on reliability values are evaluated within Pareto-optimal set and appropriate solution components are proposed to be chosen by the decision maker.

3 - Undertime Replacement Modeling in Maintenance Theory

Xufeng Zhao, Khalifa Nasser Khalifa, Abdelmagid S. Hamouda, Toshio Nakagawa

Most operating units are repaired or replaced when they have failed. However, it may require much time and suffer higher cost to repair a failed unit or to replace it with a new one, so that it is necessary to replace the unit preventively before failures. In order to replace an operating unit preventively that is running successive works with cycle times, this paper proposes a new replacement policy called as undertime replacement. We have modeled overtime replacement in which the policy is done at the first completion of some working cycle over a planned time T; however, the case for opportunistic replacement when the last cycle of successive works competes before time T has not been considered. From the above viewpoint, we give two points in time, i.e., decision variables of To and T for an interval [To, T], in age and periodic replacement modelings. We formulate the expected replacement cost rates and obtain optimal To and T to minimize them analytically. Not only that, we compare the above undertime replacement with replacement first and last with number N of working cycles to show the respective superiorities. Finally, we give an extended model and its optimization where the unit is replaced only at failures during and after [To, T]. All discussions are presented analytically and numerical examples are given when each cycle time is exponential and the failure time has a Weibull distribution.

4 - Similar facility clustering method based on the failure time distribution and FDC data
Youngji Yoo, Jun-Geol Baek

In the semiconductor manufacturing process, there are dozens of similar facilities for producing semiconductor chips or wafers. However, each facility has a different characteristic because various kinds of products are produced on a single facility. Therefore, the facility health states are different according to characteristics of the facility and it affects frequency and interval of breakdown. The breakdown of facility is directly related to the quality of products produced by the facility. In general, all facility is assumed to have the same property and the same management criteria is applied. However, it is necessary that facilities are grouped by similar characteristics and facilities have to be managed to reflect the characteristics of each facility group. For example, if there are two facilities with different breakdown frequencies, the preventive maintenance period of facilities have to be set different from each other. In the paper, we propose the similar facility clustering method using extracted feature based on the breakdown time distribution and FDC (Fault Detection & Classification) data. During the manufacturing process, large amounts of data related to the health or the state are collected from each facility. Therefore, the feature which represent the characteristics of facility is extracted from the data and we perform a clustering of facilities with similar characteristics.

■ TB-34
Tuesday, 10:30-12:00 - John Anderson JA5.07, Level 5

Computing and OR

Stream: Computing
Invited session
Chair: *Gerhard-Wilhelm Weber*
Chair: *Francesc Solsona*

1 - Unrelated Parallel Machine Scheduling with Sequence-and-Machine-Dependent Setup Times: An Exact Branch-and-Price Algorithm and its Parallel Implementation on HPC Systems
Gerhard Rauchecker, Guido Schryen

We propose and computationally evaluate an exact algorithm for solving the parallel machine scheduling problem on unrelated parallel machines with non-batch sequence-and-machine-dependent setup times, machine eligibility constraints, and a total weighted completion time objective function. This problem is NP-hard in the strong sense. An emerging application for this problem is, among others, the assignment and scheduling of rescue units as part of the response phase of disasters. We formulate the problem as a binary linear optimization model and adapt existing branch-and-price algorithms, which were formulated for related scheduling problems. Additionally, we develop efficient and effective solution heuristics for certain subproblems of the algorithm to improve its performance. We parallelize our algorithm in order to use parallel solving capacities of high-performance clusters. First, different nodes of the branch-and-price tree can be solved independently by different machines communicating via MPI. Second, the solution of a particular tree node - especially its bottleneck, the pricing problem - can be parallelized within a single machine using shared memory programming. Finally, we computationally evaluate the impact of the proposed solution heuristics on the runtime of the algorithm.

2 - Comparative Study between the Parallelization of Cluster Benders Decomposition and the Parallelization of Lagrange Decomposition Applied to Stochastic Discrete Models
Jordi Mateo, Francesc Solsona, LluisM Pla, Josep Lluis Lerida

This work compares the parallelization between two of the classical decomposition methods such as the Cluster Benders Decomposition and the Lagrange Decomposition in the resolution of stochastic discrete models. Moreover, this work presents the advantages and the disadvantages of using the parallelization of both techniques. This work wonders whether or not the usage of these techniques depending on the balancing agreement between the minimal computational time and the minimal computational resources used. The final goal is apply the best technique to solve real life models in feasible time.

3 - A Green Scheduling Policy Model for Federated Clouds.
Francesc Solsona, Jordi Mateo, LluisM Pla, Josep Lluis Lerida

This work presents a Green Strategy model for cloud systems. Cloud Federation refers to the set of software, infrastructure and platform services accessed via the Internet. We provide a solution for consolidation of VMs that make up the nodes of the cloud. In addition to guaranteeing the Service Level Agreement (SLA), the main goal is to optimize energy savings. The solution results in an equation that must be solved by a solver with Non-Linear capabilities. The SLA is usually associated with a certain level of QoS (Quality of Service). As response time is perhaps the most widely used QoS metric, it was also the one chosen in this work.

■ TB-35
Tuesday, 10:30-12:00 - Colville C429, Level 4

DEA applications: sustainable development

Stream: DEA and Performance Measurement
Invited session
Chair: *Eduardo Gonzalez*

1 - Benchmarking the metabolism of European Union countries with an eco-efficiency approach
Isabel Horta, Mafalda Silva, Ana Camanho

This research evaluates the eco-efficiency of European countries. The methodology developed is based on the use of a Data Envelopment Analysis model specified with a directional distance function. The ecological indicators reflect the resources consumed (energy and materials) and the undesirable outputs generated (total emissions and waste). The gross domestic product of the country is the desirable output of the model. The analysis extends the urban metabolism approach to the country level, and assesses 28 EU countries. The countries with a high eco-efficiency score are those that consume less resources and produce less waste and emissions given the wealth produced. The results of this analysis can guide decision makers in the design of sustainable development policies.

2 - Performance assessment in the hotel industry using data envelopment analysis: A systematic literature review
Sérgio Santos, Carla Amado

Performance evaluation of hotels has long been a topic of interest to both researchers and practitioners. Amongst the many performance measurement tools adopted, Data Envelopment Analysis (DEA), introduced by Charnes, Cooper and Rhodes in 1978, has become one of the best known and most extensively applied. Despite its widespread use it is not clear, however, what its impact has been in helping hotels improve their performance. This paper discusses the main results of a state of the art review regarding the use and impact of DEA to benchmark and improve the performance of hotels. The review comprises all the empirically based peer-review articles from the Web of Science, Scopus and Ebsco databases that specifically focus on the performance assessment of hotels using DEA. The main features and findings of these articles are discussed and their empirical and theoretical implications highlighted. The paper concludes by proposing an agenda for further research.

3 - Evaluating the influence of skipper skills in the performance of the Portuguese artisanal dredge vessels
Manuela Maria de Oliveira, Ana Camanho, John Walden, Miguel B. Gaspar

The effect of vessel skipper and biological stock fluctuations are widely recognized as potential sources of inefficiency in fisheries. However, the skipper contribution to vessel performance has seldom been addressed in the literature. This study examines the effect of social factors, such as family heritage, experience, education and professional training on the revenue efficiency of the Portuguese artisanal dredge fleet. The weekly activity of 77 vessels during 2013 is explored using a stochastic production frontier model.

4 - DEA estimation of the quality of life in Spanish municipalities in 2011

Eduardo Gonzalez, Ana Cárcaba, Juan Ventura

DEA has become an accepted methodology for the computation of composite indicators for measuring quality of life. In this study, we apply DEA to combine information on the different dimensions of the quality of life in Spanish municipalities with population over 20000 in year 2011. Economic dimensions such as unemployment or purchasing power are combined with other indicators covering aspects related to education, health, crime, environment, community, etc. The results are in the line of those obtained in previous research for year 2001. There is a clear division between north and south in terms of quality of life.

■ TB-36

Tuesday, 10:30-12:00 - Colville C430, Level 4

Teaching OR/MS II

Stream: Teaching OR/MS
Invited session
Chair: *Peter Bell*

1 - Initiatives for Teaching OR Techno-Economic Energy Modeling to Graduate Students

Denis Lavigne

The Institut de l'énergie Trottier offers four new masters in energy programmes at the École Polytechnique de Montréal. A new course on Techno-Economic Energy Modeling has been created to offer to a wide range of students an all-around tour of the subject. Students are being introduced to some simple yet powerful tools such as OSeMOSYS and LEAP which give them the opportunity to work hands on problems that enlighten greatly their understanding of what energy modeling is. An emphasis is also proposed on economics so that students learn how to communicate with professionals that may not be used to work with OR specialists.

This course is so different than what is usually proposed to students that, as its creator and developer, I am actually a candidate to the Brightspace Innovation Award in Teaching and Learning of the Society for Teaching and Learning in Higher Education (results will be known in April). This award celebrates and recognizes educators for their innovative approaches that promote student-centred teaching and learning, which is exactly what is being proposed in this course using appropriate software and an integrated approach that benefit to all students.

I will make available to the participants some of the material used in class. This will allow any professional to have a very smooth learning curve in preparing for teaching such a techno-economic energy modeling course.

2 - Master's degree program on Game Theory and Operations Research

Vladimir Mazalov, Leon Petrosyan, Elena Gubar

In St.Petersburg State University the master's degree program on Game Theory and Operations Research was developed to study the analytical tools and theoretical concepts for a wide range of applications of game theory and operation research in economics, management, labor bargaining, international negotiations, auction design, voting behavior, evolutionary ecology. This program is intended for a student, who prepares for a career in industry, science and education. The courses are designed to study theory and methods of operations research, game theory, econometrics, applied statistics, decision theory, queuing systems, applications of computer technologies and related topics.

3 - The use of case studies in teaching OR within UK universities

Christine Currie, Marion Penn, Frances O'Brien, Kathryn Hoad

This presentation will report on a project investigating the use of case studies in the teaching of Operational Research (OR) within UK Higher Education. The research consisted of two stages: a survey of OR lecturers in UK Higher Education institutions; and a collection of more in-depth conversations about particular examples of the use of case studies. We found that case studies are used to support teaching across a range of student groups and within a variety of modules and courses but there is evidence of differences in the ways that case studies are incorporated into OR teaching. The research identified that case studies are used to develop a range of students' skills, one of the key skills being the ability to transfer academic knowledge to real-life contexts. Some barriers to the use of case studies were identified in the project, including the development of new cases and writing briefing documents. However, the value of providing an approximation to a real-life experience in a safe environment is significant. The authors would like to acknowledge support for the work from the Higher Education Academy.

4 - A Software Tool for Teaching Management Analytics in Engineering Courses

Rallis Papademetriou

The plethora of management tools currently available presents an overwhelming choice to users of various needs. Commonplace is tools developed for specific markets, like OR/MS used in academia and MP-SIII used in the commercial market. MagLab is an intelligent interactive learning environment, that provides a wide ranging theoretical content, backed with calculation tools that can be used as problem solvers, implemented in an expandable and integrate-able fashion. The integration framework allows for the masking of the underlying application and applied theory by a highly intuitive and usable interface. MagLab uses the high level scripting language Tcl/Tk (standing for Tool Command Language/Tool Kit), which provides support for powerful GUIs (graphical user interfaces). The use of Tcl/Tk gives MagLab an advantage over existing packages by providing true cross platform compatibility, requiring only a Tcl/Tk interpreter per platform and removing the need for code recompilation. The interpreter is royalty free, which removes licensing issues (traditionally found with cross-platform applications) and allows MagLab to be provided in a run-from-disk format with no installation required. MagLab implements intelligent learning through the use of wizards in order to simplify and de-skill the selection and use of appropriate analytical management techniques. This simplification enhances the learning process and reduces the prerequisite theoretical knowledge required by the user.

5 - Teaching OR/MS and/or Analytics to MBAs

Peter Bell

The strong market response to "analytics" and "big data" suggests that there are benefits to including these topics in our OR/MS courses. This session will discuss ways that we might do this within the context of the OR/MS core MBA or EMBA course.

■ TB-37

Tuesday, 10:30-12:00 - Colville C411, Level 4

Sustainable Living

Stream: Sustainable Living: Cognitive, Social, Economical, Ecological and World View
Invited session
Chair: *Gerhard-Wilhelm Weber*
Chair: *Nina Kajiji*

1 - A multi-criteria assessment of the Millennium Development Goals 4 and 5A

María M. Muñoz, Antonio Casquero, Bienvenido Ortega, Jesús Sanjuán

The aim of this paper is to obtain an instrument that will enable us to assess the degree to which the Millennium Development Goals (MDG) 4 and 5A have been achieved in 43 Developing Countries using the latest available data. The 4 and 5A MDGs are essentially to reduce child and maternal mortality. The United Nations (UN) targets for child mortality are to reduce by two thirds, between 1990 and 2015, the under-five mortality rate (with three indicators: the under-five mortality rate, the infant mortality rate, and the proportion of one year old children immunized against measles). The targets for maternal mortality are to reduce by three quarters, between 1990 and 2015, the maternal mortality ratio (with two indicators: the maternal mortality ratio itself and the proportion of births attended by skilled health personnel). With this aim, we employ three different Multi-criteria Decision Analysis

techniques: PROMETHEE, TOPSIS, and the weighted sum. Through these techniques, we can obtain different rankings of achieving these objectives by countries, which allows us to classify them according to the degree of achievement of objectives.

2 - Understanding the Effect of Housing on Long Evans Rats with Active Anxiety and Addiction: Planning for Well-Being in Urban Communities

Nina Kajiji, Gordon Dash, S Tiffany Donaldson

Addiction is a serious global issue. Urban communities around the globe are saddled with the added problem of homelessness; a condition that is exacerbated by addiction. Sovereign governments are obligated to find and establish policies that can effectively address the homelessness condition of the actively addicted. Relying on new findings in neuroeconomics, we prescribe an interdisciplinary study of the physiological and neurobehavioral responses of Long Evans rats that sheds new light on how policymakers can address the societal reclamation of the affected population. Specifically, the lifespan animal model proffered in the study interrogates the effect housing environment has on the ability of the gender defined Long Evan rat to overcome anxiety and addiction. Postmortem we look for anxiety-like behavior by examination of the early-gene neural marker, c-fos. We contribute new findings that substantiate how the socially integrated high anxiety female rat develops the greatest sensitivity to addiction and therefore can return more easily to a non-addictive state. When the findings of the animal experiment are extended to urban economic public policy we are able to project how environment and gender provide an avenue by which it is possible to reduce addiction severity over time. From the animal study, we conclude that moderate density low-rise public housing is most likely to support a return to feelings of well-being among the affected population as a whole.

3 - Open Source Datadives- Illuminating hidden costs in wheelchair provision

Christopher Prior, Alison Crawford, Jon Hannah

Rationale NHS IQ has used a new approach modelled on the 'hackathon' methodology of crowdsourcing ideas, data and analytical power to address tricky questions where there is no central comprehensive data repository. Aims The aims of this work were to understand: ●Cost of provision of wheelchairs by voluntary and self-funded ●Potential supply cost of unmet need ●Avoidable spend caused through unmet need ●The 'virtual' data dive methodology, in order to develop an approach that might be applied more generally. Approach A virtual datadive brings together a diverse team from different areas e.g. wheelchair users, suppliers, policy experts and analysts. Together they identify the scope and aims, and work collectively on analyses and outputs, reviewing and evolving as insight emerges. Previously, datadives are typically face-to-face events. This project proposes a virtual datadive, making use of technology to make participation as wide as possible. However, applying these technologies to this type of working is new and requires some testing to find best practice Findings This paper will present the findings of this proof of concept activity to include the following: ●Use of social media and virtual networks to recruit and manage volunteers for a datadive ●Use of virtual tools for managing data and conversations about data ●Useful ways to share the insight generated by a datadive ●Best Practice for a successful virtual datadive

4 - Modeling, development and analysis of sustainable facility location problem

Saeedeh Anvari, Metin Turkay

Nowadays, sustainability in design and operation of supply chain systems is a very important factor. A review of literature shows less work is available on sustainable development, especially on social dimension. Also, a sustainable decision-making methodology in supply chain management which accounts for environmental, social and economic dimensions simultaneously is not purposed in most of the previous work. We propose a methodological approach which conforms to triple bottom line accounting (economic, environmental and social pillars) for supply chain management problems. The proposed approach is based on the design of an algorithm to define the important parameters and parameter indicators and respective measurement method. Then each objective is designed mathematically using the defined indicators. Finally, a multi objective model is proposed where each objective belongs to one of the pillars and can help to achieve sustainability in network design when considered simultaneously. The numerical experiments show that the optimal network configuration changes with new considerations and can help the decision maker finding the proper alternative. This method also can help the decision makers to be friendly to environment and society by some more investigation cost.

This extra cost is interpreted to be returned by less cost of removing effects of discarding environmental and social factors and more profit of good reputation.

■ TB-38

Tuesday, 10:30-12:00 - Colville C410, Level 4

Humanitarian Operations Research - Medical Applications

Stream: Humanitarian Applications
Invited session
Chair: *Silja Meyer-Nieberg*
Chair: *Erik Kropat*
Chair: *Jiun-Yu Yu*

1 - Multicriteria Patient Transportation Planning

Melanie Reuter-Oppermann, Andrea Raith, Andrew J Mason

The German Emergency Medical Service (EMS) system is responsible for executing patient transports when a patient needs to be transported in an ambulance to, from or between hospitals while the attendance of an emergency medical technician is necessary. For many EMS regions, a high percentage of transports is known in advance, but short-term requests often need to be handled immediately throughout the day. In this research we want to schedule patient transportation requests and assign them to transportation ambulances. First, we present a corresponding formulation for the patient transportation problem and extend it to a multicriteria formulation. In order to solve larger instances in reasonable time, we propose a column-wise neighborhood search. A starting solution is determined by a best insertion heuristic. As sometimes only very few patient transportation requests are known in advance, an online approach is studied that assigns requests to ambulances whenever they become idle. The approach is very close to the current method used in German EMS practice. It considers the current location of the ambulance, the pick-up location as well as a possible look-ahead on future requests when assigning a patient transport to an ambulance. We test our formulations and approaches using a set of randomly generated instances that are based on real data from an EMS region in the southwest of Germany and compare the solutions for the different approaches.

2 - Improving Emergency Medical Services (EMS) with Time-Region-Specific Cruising Ambulances

Jiun-Yu Yu

Emergency Medical Services (EMS) refers to both patient transport and medical support solution for people with illness or injuries. Recent clinical evidence shows that for out-of-hospital cardiac arrest (OHCA) cases the response time, time spent by the ambulance to arrive at the scene, is critical to the survival rate. To reduce the response time, a time-region-specific ambulance cruising policy is proposed. Analytics and GIS are applied to generate the joint time-region distributions to identify high frequency grids. Simulation models are built to examine various ambulance stand-by and cruising policies. The interim results show that the EMS performance can be significantly improved by re-allocating current resources.

■ TB-39

Tuesday, 10:30-12:00 - Colville C405, Level 4

Business Intelligence and Knowledge-Based Decision Support

Stream: Decision Support Systems
Invited session
Chair: *Pascale Zaraté*

1 - RAID-B2K, Transforming BPMN Conceptual Schemas into Kettle Execution Primitives

Vasco Santos, Orlando Belo, Bruno Oliveira, Claudia Gomes, Ricardo Marques

There are a lot of tools on the market for designing and modeling ETL systems, covering its entire development life cycle. However, the vast majority of these tools use proprietary methodologies, specific notations, and very specific tasks, which do not contribute to their understanding and consequent application. Conceptual modeling is a very useful and valid activity for the understanding and implementation of any ETL system. In this paper we present a translation tool for conceptual models, with the ability to reduce the "gap' that exists usually when we need to translate a conceptual model for an equivalent physical one. Throughout this article will demonstrate that it is possible to translate automatically ETL systems conceptual models (tasks, working flows, etc.) developed in BPMN into the environment of a specific ETL systems implementation tool. After a careful study of the most relevant specificities of a BPMN model specification, we choose Kettle (Pentaho Data Integration) as the tool to receive the models translated by the tool we implemented. The BPMN models were built so that they can produce schemes, simple and easy to perform, for a specific execution environment (RAID). This allowed us to demonstrate the utility of the tool in the translation, validation and generation of the correspondent physical schemas, which can be performed in Kettle. These ETL physical schemas were designated by ETL skeletons - a set of execution primitives.

2 - Decision parameters affecting last mile delivery performance in Indian e-commerce companies
Partha Datta

A framework is designed to evaluate last mile delivery performance of Indian e-commerce companies after thorough review of literature on factors influencing last mile delivery performance in e-commerce companies. Three major drivers are identified to affect last mile delivery performance: delivery time, price and quality. An influence diagram is plotted to highlight the key enablers and hindrances to these factors. Several hypotheses are generated linking these factors for further empirical or simulation based studies.

3 - Expert knowledge elicitation for the creation and validation of models in the absence of data
Laura Kreiling, Abigail Hird

In the absence of an abundance of data, resource planners use unstructured estimations as a source of decision making information. Challenges associated with such an approach are: a lack of transparency; slow and lagging response to information demands; poor consistency and agreement; cost intensive collection and ambiguous accuracy (Hird 2012). By developing a technique based on the efficient and structured collection of expert estimations, Hird (2012) overcomes such challenges. In applications to date, a small amount of legacy project data has been available to validate such methods thereby encouraging confidence in model results. This research explores the instance where no data is available for validation of the model. We propose the use of the Delphi method in combination with the technique proposed by Hird (2012). Through case studies, the technique is employed in a UK-based automotive firm. The objectives are: to identify suitable parameters and to evaluate the suitability of Delphi in this context. Initial findings suggest that Delphi is a legitimate means of validating quantitative models and developing confidence in model use. The process of applying Delphi engenders a sense of model ownership and encourages evaluation of current planning practices. Unstructured resource estimation in the absence of data for forecasting model development and validation is a widespread and long standing issue. Our findings also address the issue of expert knowledge retention.

4 - Implementing ERP under constrained resources: a nonlinear programming based decision support system
Ying Xie

By conducting regression analysis on surveys with small and medium sized enterprises (SMEs), this paper develops a constrained nonlinear programming based decision support system for enterprise resource planning (ERP) implementation (CNL_DSS), and verifies it through simulation. The application of CNL_DSS is demonstrated in three case studies, in which CNL_DSS can identify requirements to achieve predetermined goals prior to implementation. The average ERP implementation outcomes achieved by allocating resources as suggested by CNL_DSS are preferable to the observed results, with a multi objective trade off between high ERP implementation performance level and low cost. A post-study survey and interview were conducted with staff leading ERP projects in the case companies, collected positive feedback on the use of the CNL_DSS, in supporting adopting CNL_DSS prior to implementation. Contributions from this research are: it offers an analytical model to accurately monitor the progress made, and

cost consumed, by each critical success factor (CSF) against time; it determines the priorities of CSFs, based on which resources are allocated to achieve the predetermined target, and it evaluates the impacts of changes to the resources allocations.

■ TB-40
Tuesday, 10:30-12:00 - Colville C511, Level 5 (not used)

Ethics and OR 2

Stream: OR and Ethics
Invited session
Chair: *Erik Kropat*
Chair: *Gerhard-Wilhelm Weber*
Chair: *Pierre Kunsch*

1 - International commerce and pollution quota
Salvador Sandoval

This work calculates the optimal pollution quota for an oligopolistic industry of a homogenous good under reciprocal dumping conditions. The firms count on the appropriate technology to decrease the pollution and can decide the amount of emissions generated. In this model the optimal quota depends on the amount of marginal disutility to pollute as well as the pollution abatement cost. Also, it examines which are environmental policies that the government must apply to maximize the benefits for consumers, firms, involved countries and the environment. The model contains these variables in a social welfare function. The model concludes two important results. In the first case, if the abatement cost is very small compared to the marginal disutility of pollution, the optimal policy consist to impose the most restrictive quota, in this case the government gives priority to protecting the environment, even if it means an increase in the final price of the good produced while reducing the benefit of consumers and corporate earnings. In the second case, if the abatement cost is very large compared to the disutility of pollution, then the government allows some emission of pollutants, thereby the cost of production will be reduced, which has a favorable impact on corporate profits and on the consumers pocket, although the emission of pollutants increased significantly in turn increases the social cost of pollution.

2 - Re-examination on the Managerial Efficiency by Diversity Management — Recent Evidence from Japan
Motohiro Hagiwara

Declining birth rate, and an aging population, it has long been recognized in Japan that the female workforce or other source of labor need to be better utilized in the Japanese labor market. Among developed countries, Japan lags in terms of the utilizing its female or other kinds of workforce. Various interrelated factors—including the custom of lifetime employment, long working hours for full-time employees, lack of measures to support work-life balance, discrimination against female, foreign or elder employees in the workplace, and a lack of job market awareness among those kinds of workers —are responsible for this lag in various kinds of diversity management. However, if diversity management in workforce can enhance corporate earnings and competitiveness (a growing need in the current economic environment), then actively promoting the utilization of new source of workforce may help Japanese companies improve their performance and enhance the international competitiveness of Japanese economy. But it was reported in the context of Norway's limited human resources, that country's 2003 mandate that 40% of directors be women led to the rapid appointment of women to boards, a consequent increase in the number of inexperienced directors, and a resulting decline in corporate performance. This study found facts giving the same implication in Japan. Clearly, more research should be conducted on the topic of institutionalizing quotas for female executives.

3 - From Human Development Index to Human Development Effectiveness
Bijaya Krushna Mangaraj, Upali Aparajita

The introduction of human development index (HDI) as an approach for measuring human development has been initiated by United Nations Development Programme for ranking nations globally. This composite index measures three major dimensions: standard of living, longevity and knowledge based on an averaging procedure with an unattainable ideal target. Instead of simple rank obtained by a country based on its HDI value, in this paper, human development has been benchmarked based on empirical observations capturing the best

practicing countries. The concept of effectiveness as the simultaneous achievement of target by these dimensions has been introduced in human development as a measure of performance. A multi-criteria human development effectiveness (HDE) model has been developed, where we assess relative performance of the countries based on a benchmark. A methodology based on competitive-cum-compensatory fuzzy goal programming has been utilized for the determination of the benchmark to assess HDE values as the relative effectiveness of the countries in the range [0, 1], which also provides their categorical classification as effective vs. ineffective. The results of this re-assessment for the year 2014, giving a different ranking of countries, and above all, providing a new perspective on developmental imbalances has been presented. Apart from the global assessment, this methodology can also be applicable at the national as well as local level.

■ TB-41

Tuesday, 10:30-12:00 - Colville C512, Level 5

Spatial Multicriteria Evaluation: Insights and Applications II

Stream: Multiple Criteria Decision Aiding
Invited session
Chair: *Gilberto Montibeller*
Chair: *Valentina Ferretti*

1 - Environmental problem management through multi criteria decision analysis and Social Network Analysis. Case Study: El Cocuy National Park
Jorge Romero, Felix Antonio Cortes Aldana, Monica Garcia-Melon

A.Purpose - The purpose of this paper is to propose a methodology for addressing complex (social, environmental and economic) problems, by combining multi-criteria analysis and social network analysis. And to investigate the linkage between Participatory decision making and the group decision making in MCDA.

B. Design/methodology/approach - The complex and dynamic nature of environmental problems requires flexible and transparent decision-making that embraces a diversity of knowledges and values (Reed 2008). Three tourist paths are visited for observation; recording GPS points in each environmental damage. The first tour takes place in January 2014, the second in November 2014 and the last in January 2015. Covering the paths corresponding to the snowy peaks: Ritacuba blanco, Concavo, Concavito. Next, the environmental problems are ranked by a qualitative approach (AHP) and by a quantitative approach (Entropy method). Next, by a social network we can see influence paths for design a participatory group ANP - VIKOR process.

C.Findings — The study develops a Group MCDA-SNA methodology for participative decision making, with multiple and diverse decision making groups.

2 - Personnel Selection with Utility Range Based Interactive Group Decision Method
Halil Şen

Due to the increasing competition of globalization, selection of the most appropriate personnel is one of the key factors for an organization's success. The importance and complexity of the personnel selection problem call for the method combining both subjective and objective assessments rather than just subjective decisions. The aim of this paper is to develop a new method for solving the decision making process. Utility range based interactive group decision method is proposed for solving this complex problem and selection of the personnel which has the highest utility. Main theme underlying the method is every group member wants to compare their partial utility information with other group members. This procedure reflects the incomplete information as linear range because it can count easily from partial utility information. Range type makes the incomplete information effective and efficient to demonstrate the group members. In addition to this, range type utility information makes easy to compare every group members' utility information with group's information and collecting the each group member's utility information within group's utility information. To obtain group utility, preference aggregation method is used. Interactive procedure helps to make consensus of the group. Utility information calculated by using optimism coefficient which is determined by the group. A numerical example for personnel selection is given to illustrate the proposed method finally.

3 - Land suitability analysis for wetland location: a spatial multicriteria approach
Elena Comino, Valentina Ferretti

Riparian wetlands play a key role as ecological services. Due to their increasing loss and conversion to other land uses, the landscape has been modified and rivers and streams have lost their biological, self cleaning and hydraulics mitigation functions. For all these reasons it is crucial to restore, maintain and create riparian wetlands. But, how is it possible to establish which is the most suitable area along a river basin where to design a wetland combing natural/human and engineering needs? In this study a spatial Multi-Attribute Value Theory (MAVT) model has been developed to define the most suitable area to be transformed into a wetland in the Val Pellice river basin (Italy). One of the advantages of the spatial MAVT method is that it provides a structured approach to address the problem using both quantitative and qualitative data. Various environmental attributes, such as land cover, surface hydrography, fluvial index, lithology, slope, valuable areas of natural interest, were evaluated by different stakeholder who participated in the innovative decision process. The added value of the present paper lies in the explicit consideration of the spatial distribution of all the attributes which contribute to determine the suitability of an area to become a wetland. The spatial MAVT approach proved to be useful for supporting river basin management and planning. This research is part of an Interreg project (Italy-France), in the Alcotra programme 2007-2013.

■ TB-42

Tuesday, 10:30-12:00 - McCance MC301, Level 3

Case studies in OR/Analytics 4: Human Aspects

Stream: Case Studies in OR / Analytics
Invited session
Chair: *John Ranyard*

1 - Getting OR Applied
Elise del Rosario

This presentation describes how 3 well-conducted OR projects met different implementation fates and demonstrates the importance of having a Project Champion in the client organisation.

The first project involved rationalization of the brewery facilities in China by a Philippine multinational. A model was developed to determine which of the existing brewery and sales networks joint ventures must be retained or disposed of. The OR team was consulted every step of the way, including sensitivity analysis on the price to pay per share to increase holdings in a joint venture, and the results were successfully implemented. In the second OR project, the recommendation to use two contractors to operate the major harbour in Manila was used by a lobby group to contest the original intention for a single contractor. The two-contractor scheme is now in place. The third project optimized the dispatch of energy generating facilities in the Luzon island grid in the Philippines. The results of the study showed rules of thumb used in the manual dispatching operations were not optimal. The study results were not implemented soon after the project sponsor, the Energy Secretary, was replaced.

2 - Lessons Identified from Assessing Organisational Health within the UK Ministry of Defence
David Lowe, Louise Martingale, Anita Murray-Jones, Mike Yearworth

In 2014 the Defence Science and Technology Laboratory (Dstl) was tasked to design a method for assessing the health of the UK Ministry of Defence (MOD) Acquisition System. The Dstl consultancy team used the Viable Systems Model to structure an assessment method and engaged with stakeholders drawn from across MOD in order to test and refine this method before delivering results in January 2015. The presentation will (i) provide an overview of the task, (ii) describe the design process, (iii) detail the results, and (iv) reflect on the lessons identified before (v) looking ahead to future challenges in this area.

3 - The Human Element in Prioritizing R&D Projects
Ian Seed

Prioritizing research & development activities is a key aspect in a modern business. There is always more work to do than funding available. In recent times, the recession has meant the funding available has reduced dramatically. Hence, a systematic approach to prioritizing projects to those that derive the greatest benefit has taken on an even greater importance. Even more challenging has been the fact that funding availability has been extremely volatile. In other words, the funding initially thought to be available, and used for prioritization, has been cut even further, late on in the process.

This paper will describe our approach to prioritization that takes into account volatile funding streams that is flexible enough to cope with what is happening right now in many organizations.

The case study will show our recent work carried out for the United States Department of Energy. The paper will describe the process and mechanics of the prioritization process: one where we used resource allocation techniques to developed a range of portfolios for different funding allocations.

The paper will, however, focus more on the human element of the process. How the participants engaged with the process, what caused problems and what went well. We will examine the role of different stakeholder groups in the process and, ultimately, how the prioritization process delivered the information to support the submission to the US Congressional Budget Committee.

4 - Using Simulation and Cloud-based Computing to bring Optimization to SMEs
Liam Hastie

Cloud based computing is an exciting and emerging area of development that could revolutionize how we analyse Processes Simulations and how Operational Research is conducted. The search is now on to find the best ways of integrating this technology in a way that is accessible and practical for all organizations including Small and Medium-sized Enterprises. As part of a wider Industrial Collaboration Project the configuration, staffing and order fulfilment cycle time of a manufacturing organization was investigated through the development of a simulation model. The same simulation was then set an optimization goal to return an optimal configuration of machine numbers and staffing. By accessing a Cloud based computing system the execution time of the optimization analysis was radically reduced. This session will outline how the simulation was constructed and linked to a Cloud network to increases the practicality of the approach to real-world application. Lessons learned during the projects are also presented with a focus on the challenges of managing stakeholder engagement and expectations.

■ **TB-43**

Tuesday, 10:30-12:00 - McCance MC303, Level 3

Defence and Security Applications VI

Stream: Defence and Security Applications
Invited session
Chair: *Ana Isabel Barros*

1 - Integrated Survivability Approach to Large Aircraft Operational Risk
Ben Maddison

Survivability is the ability to complete a mission in the face of a man-made hostile environment. Integrated Survivability (IS) is the Systems Engineering (SE) methodology to achieve optimum survivability at an affordable cost. Attempting to achieve optimum survivability is a wicked problem, because an optimum solution for one mission may be sub-optimal for another. The presence of an evolving enemy capability adds further complexity. This presentation will discuss the various factors that are considered within IS assessment for Air Transport aircraft, including threats; mitigations and military context. Dstl have developed a risk assessment methodology designed to integrate all these factors so that different risks can be prioritised. The process was developed along similar principles to safety risk assessment using likelihood and severity but using 3-axes rather than 2. These are:

● Likelihood of threat encounter; ● Likelihood of threat engagement/hit ; and ● Severity of any hit on the platform.

The output from this assessment can be used to help MoD identify research priorities and understand the levels of risk associated with different threats and mitigation options.

2 - Optimal short-term fleet planning incorporating flying and maintenance constraints
Robert Dell, David Marlow

We consider the development of an optimal short-term plan for a fleet of naval combat helicopters. The fleet must have a certain number embarked on ships at all times, and meet monthly and annual flying requirements for both the embarked and ashore fleet components. The aircraft need to be regularly maintained, with frequent inspections (e.g. once per week for each aircraft), phased services and depot-level maintenance all required. Each type of maintenance is conducted in a different facility, each with different capacities and manpower rates of effort. We seek to maximize the serviceability (i.e. the percentage of aircraft able to fly) of the fleet while prescribing a daily flying and maintenance plan over a period of up to one month that meets the above requirements. We present an integer-linear program and preliminary results for a small naval helicopter fleet.

3 - Holon: A flexible and easy-to-use tool for facilitating the assesment of the operational effectivness of early ship concept designs
Guido Veldhuis

In the next 20 years about half of the ships in the current fleet of the Royal Netherlands Navy will be decommissioned and replaced by new ships. TNO was asked by the Netherlands Defence Materiel Organisation (DMO) to develop a simulation tool to support the design of ship concepts in an early stage. During this phase a large number of ship concepts are evaluated in rapid succession and in an iterative process following the NATO Total Ship Systems Engineering (TSSE) process. The tool, called Holon, facilitates exploring the operational effectiveness implications of a wide range of system variations (e.g. radar and weapon systems, and organic units like helicopters) or system performance variations (e.g. ship speed and sensor detection range). This facilitates the use of simulation as an integral part of the iterative design process. Holon does so by providing the user with an environment to design experiments, perform batch simulations and analyse the results. Holon is a generic 'jacket' that can be linked to different simulation models. Currently the agent-based simulation model MANA is used which was developed by the Defence Technology Agency (DTA) in New Zealand. In the upcoming years, it is anticipated that Holon will be used to conduct exploratory studies as part of replacement projects that aim to design next generation frigates, MCM vessels and submarines.

4 - Evaluating the Map Aware Non-Uniform Automata (MANA) Model in Support of Coastal Surveillance Planning and Assessment
Cheryl Eisler, Peter Dobias

As resources grow more constrained over time, the impact of a potential reduction of availability of particular sensors on the ability of navies to monitor their area of responsibility is becoming a pressing question. In some cases, these changes in availability might happen on short notice; consequently, the impact assessment may be required within tight deadlines. This would not provide enough time to conduct high-fidelity analysis using tools such as the Systems Toolkit (STK). Instead, lower-fidelity models with short development times and significant flexibility may be required. Agent-based models are one such approach; they are characterized by the use of abstracted autonomous entities that behave in accordance with pre-defined heuristics. These models capture nonlinear dynamics inherent in real, multi-scale, multi-actor situations, and can exhibit emergent behaviour. Canada has previously employed New Zealand's model, known as MANA, to a wide range of land-based scenarios and to a limited number of maritime vignettes. Building upon this, MANA is evaluated for its overall suitability for maritime surveillance modeling. The assessment includes consideration of how well MANA meets required and desired capabilities, as well as a number of scenarios that assess the performance and reliability of the results using Monte Carlo methods. We present the assessment matrix developed, results, examples of how MANA could be used, and a discussion of where its usability breaks down.

■ TB-44

Tuesday, 10:30-12:00 - McCance MC319, Level 3

Fuzzy Decision Support Systems

Stream: Fuzzy Decision Support Systems, Soft Computing, Neural Network
Invited session
Chair: *Seda Turk*

1 - Inventory Planning With Supplier Selection Using Interval Type-2 Fuzzy Sets
Seda Turk, Simon Miller, Ender Özcan, Robert John

Evaluating and selecting suppliers is a crucial and challenging task for all partners within a supply chain to ensure maximisation of service level and minimisation of cost. Failure to achieve this results in an inefficient and uncompetitive operation that is unlikely to succeed. In light of this, supplier evaluation and selection are of ongoing interest within the operations management research community. Also, efficient inventory management is critical for companies to achieve competitive advantages. In recent years, there has been a growing interest in the area of selection of an appropriate supplier along with good inventory planning.

In this study, we investigate supplier selection informed inventory planning in a two-stage approach employing Interval Type-2 Fuzzy Sets (IT2FS) and Simulated Annealing (SA) to deal with both supplier selection and inventory planning of a supply chain problem. In order to rank suppliers, in the first stage, the supplier selection problem is dealt with using IT2FS. We present an inventory model that incorporates information from the first stage is developed to capture the influence of supplier risk on the total cost of supply chain operation. In the second stage, SA is applied to the problem balancing the trade-off between supply chain operational cost and supplier risk. In this work, we investigate our approach using different scenarios and scalarisation techniques for SA to deal with two objectives, concurrently.

2 - Computing the Accurate Centroids of Interval Type-2 Fuzzy Sets
Jiawei Li, Robert John, Graham Kendall

Defuzzification of type-2 fuzzy sets is considered to be defuzzification bottleneck because of its computational complexity. No closed-form operator that generates accurate solutions has been found so far. In this research, we prove that the closed-form Nie-Tan operator, which membership function is exactly the average of the upper and lower memberships, is a representative embedded set and it computes the accurate centroids of interval type-2 fuzzy sets.

3 - A Fuzzy Linguistic Approach for Software Requirements Prioritization
Vassilis Gerogiannis, Dimitrios Tselios

We present a fuzzy linguistic approach to prioritize software requirements based on 2-tuple fuzzy linguistic terms. The main aim of the approach is to consider the prioritization of business goals, non-functional and functional requirements of a software system in a unified framework. The approach requires from a group of requirements engineers (REs) to rate how much each business goal is influenced by each non-functional requirement. Then, REs evaluate the importance degree of each non-functional requirement for achieving each functional requirement. Dependencies between non-functional requirements are also considered. We follow a group, similarity degree-based algorithm to aggregate all linguistic assessments and the result is an objective ranking of the functional requirements with respect to their risk of implementation. The approach was implemented in the context of the SPRINT SMEs project that is supported by the Operational Program "Education and Lifelong Learning" co-financed by European Union (European Social Fund) and Greek national funds in the context of the program ARCHIMEDES III.

4 - May the success be a matter of degree? Fuzzy Examination and Scoring through Multiple Choice Questions
Aycan Kaya, Ali Fahmi, Cengiz Kahraman

We usually deal with binary assessments, i.e., true and false. However, Zadeh proposed fuzzy sets and membership functions whose possible values are between zero and one. Fuzzy logic enables us to judge fairly by providing values between zero and one as membership function of a particular set. Fuzzy sets could be used in many old-fashioned aspects of our life in order to reach better performance. Examination is applied in all educational centers and scoring is a potentially difficult process to judge. Exams with multiple choice questions are one of the examination types. In this study, we propose an assessment system for fuzzy multiple choice questions which choices have a degree of correctness. We let one choice be the exactly correct answer and other choices be the results of the most common mistakes that students make in the exam even they gradually know the solution of the problem. We suggest the degree of correctness to be determined by related lecturer(s). We applied this approach in engineering economics course at the Istanbul Technical University and received a meaningful difference between classical approach and our proposed approach. We conclude that students' marks from the fuzzy examination and the student ranking are more accurate.

■ TB-45

Tuesday, 10:30-12:00 - Graham Hills GH514 Lecture Theatre

Public Transport Systems

Stream: Optimization of Public Transport
Invited session
Chair: *Stefan Ruzika*

1 - Improving Public Transport Accessibility via the Optimisation and Synchronisation of Schedules for Key Transport Modes
Michelle Dunbar

As the population within modern metropolitan cities continues to grow, greater population dispersion means that daily commuters are increasingly faced with longer commute times and journeys consisting of multiple legs; often involving more than one mode of transport. In a bid to discourage the use of the private motor-car and facilitate the uptake of public transport, there is a developing trend towards the construction of centrally-located Transport Hubs, allowing passengers to connect with multiple modes of transport. To assist passengers in connecting with their outbound mode more efficiently, it is desirable to synchronise connecting modal services within the Transport Hub. We consider the problem of designing shuttle-bus routes for passengers connecting with one of four different transport modes at a Transportation Hub. We seek to minimise the average waiting time for passengers, the cost of missed connections at the Hub and the total travel time. Furthermore, we incorporate time-of-day effects and passenger heterogeneity with respect to value-of-time. In addition to commuters, the framework developed is amenable and directly extensible to the perishable good delivery problem for which items possess heterogeneity in delivery priority. Our model is posed as an extension of the vehicle routing problem with time windows, and solved using column generation. We provide a brief outline of our optimisation formulation and preliminary results for a number of datasets.

2 - Lagrangian Relaxation-based Approach for the Crew Scheduling Problem
Manuel Fuentes, Luis Cadarso, Ángel Marín

This paper presents a new approach to the Crew Scheduling Problem in rapid transit networks, where distances are typically short and frequencies high. This fact leads to combinatorial complexity. While the Crew Scheduling Problem has been typically tackled as a set covering or set partitioning problem, we base our new approach on sequencing. The structure of the resulting mathematical model can be exploited with decomposition methods. While traditional approaches based on set covering/partitioning problems use column generation for the solution process, we use the Relaxation Induced Neighborhood Search (RINS) heuristic. Because RINS does not guarantee the optimal solution, we use the Lagrangian Relaxation to obtain lower bounds to the original problem and demonstrate we obtain near-optimal solutions with the use of the RINS. We present computational experiments drawn from RENFE, the main Spanish train operator.

3 - Optimized fare inspection in commuter rail systems
Truls Flatberg, Lars Bakke Krogvig

In most public transport systems passengers are required to purchase tickets to travel. As physically restricting ticket-less passengers from entering the system often requires costly infrastructure and personnel, many transportation companies opt to use the honour based proof-of-payment system to collect passenger fares. In a proof-of-payment system passengers are free to enter the system without being checked for tickets, but risk being inspected and fined along the way by fare inspectors. This talk will focus on the planning of patrol units for fare inspection in the commuter rail system around Oslo serviced by Norges Statsbaner (NSB). We model the problem as a Stackelberg game where the patrol units commit to an inspection strategy, and the passengers optimize their own cost based on knowledge of the inspection probabilities in the network. By using mathematical optimization and specifically column generation we construct an optimal set of patrols plans and a corresponding probability distribution. Inspections are randomized by sampling patrols each work day. Solving the optimization problem presents computational challenges and we present a heuristic method for finding approximate solutions. The solution method is validated through several numerical experiments using example train networks inspired by the actual NSB local train network.

4 - Single- and biobjective timetabling for shuttle buses
Carolin Torchiani, David Willems, Stefan Ruzika

An important issue during the organization of a major public event is transportation planning. If the public transport system or the parking facilities are not dimensioned for the expected number of attendees, commonly a shuttle bus system is put in place. After locating the bus stops and choosing the travel routes, the next planning step is timetabling for shuttle buses.

Since the travel routes from the bus stops to the event are (substantially) fixed after locating the stops, the travel time of the attendees cannot be influenced by the timetable. The waiting time of the attendees remains as regulating screw for the quality of service of the timetable.

We introduce a network flow problem for minimizing the waiting time of the attendees. The problem can be interpreted as multicommodity flow over time, in which both the buses and the passengers represent a commodity. The two commodities are linked by capacity constraints modeling the interaction between buses and passengers.

In a first step, we minimize the total waiting time of the passengers. Afterwards, a second objective function minimizing the maximum of the individual waiting times is added. We develop solution algorithms for finding optimal timetables. The model is applied to a realistic scenario.

■ TB-47
Tuesday, 10:30-12:00 - Graham Hills GH513, Level 5

MAI: Stand out ... for the right reasons!

Stream: Making An Impact 3 (MAI 3)
Invited session
Chair: *Rosemary Byde*

1 - Stand out ... for the right reasons!
Rosemary Byde

Get inside the mind of a busy manager with CV fatigue to help you get interviewed and selected for that job you've always wanted. Find out what they notice, what they like and what makes them move on to the next in the pile. Take a closer look at the interview process to see how to sell yourself and get the right job for you. If there's a question you've always wanted to ask about CVs and interviews, make sure you come ready to ask and find out the answer!

■ TB-48
Tuesday, 10:30-12:00 - Graham Hilils GH510, Level 5

Location (Contributed)

Stream: Location
Contributed session

Chair: *Jörg Kalcsics*

1 - Reverse logistics network design for Waste Electrical and Electronics Equipments (WEEE): An application in Turkey
Aycan Kaya, Erhan Ates, Anıl Ata, Ferhan Çebi

Turkey has been a candidate country for EU membership since 1999. First WEEE Directive entered into force in February 2003 in EU, Turkey adopts legislation aimed at transposing EU directives related to WEEE. Therefore, Ministry of Environment and Urbanization published WEEE directives in Turkey in May 2012. Since then, to adopt this new legislation, electrical and electronics equipment producers in Turkey try to find a solution with minimum cost. In this study, we develop a reverse logistics network model to determine the best possible locations to collect sufficient amount of used products with minimum cost for an EEE producer that has a large market share in Turkey. First of all, we try to estimate the number of WEEE that will occur in cities until 2020 according to the population increase rate in Turkey. After this phase, we develop a mixed integer programming model aiming to minimize fixed opening costs of facilities, transportation costs, and disposal costs while maximizing revenue coming from the sales of products which are recovered from the used products. This mathematical model decides where to open new facilities (depots/sorting centers) and the amount of used products that are sent from waste collection centers of Municipalities to depots/sorting centers. Also, this model decides on the amount of products that will be sent from depots/sorting centers to disposal or recycling centers.

2 - A two echelon hybrid capacitated cost optimization model applied to facilities location in a fishing distribution network
Arnaldo Vallim, Ricardo Bogossian

Brazil has a large fishing potential due to its coast with the Atlantic ocean and a large consumer market, mainly in large centers, as Sao Paulo and Rio de Janeiro. On the other hand, there is the need to preserve nature ensuring the sustainability, as well as, the economy and food supply for the population, as a low price. This study approaches the problem of the fish distribution chain in Brazil, aiming to minimize waste, and thereby reducing costs and the environmental impact. The problem under study is to define the locations of a set of distribution centers spread over the country, as well, the flows in the logistics network, involving the distribution centers, production regions and consuming areas. Solve the facility location problem is a fundamental strategic decision, since facilities configuration impacts the whole logistic operation, influencing level of service and all logistics cost components. The problem solution is in general obtained through the use of mathematical programming models, which usually, look for optimal locations in a logistic network, among a given number of candidate nodes. This research addresses this problem proposing a two-echelon multi-commodity model, based on a hybrid solution, combining mixed integer linear programming with a cost model, structured as a set of inventory costs equations. The model was applied to the Brazilian real case for fishing distribution, and the application has showed the model applicability to real world problems.

3 - A modelling framework on distance predicting functions in continuous location problem
Idowu Ademola Osinuga

Continuous location models are the oldest models in locational analysis dealing with the geometrical representations of reality, and are based on the continuity of location area. The classical model in this area is the Weber problem. Distances in the Weber problem are often taking to be Euclidean distances but almost all kind of the distance functions can be employed. In this framework, we examine an important class of distance predicting functions (DPFs) in location problems all of practical relevance. We also show how recent advances in the use of these DPFs have significantly improved the ability to model travelling distances in location models. The new metrics are discussed for both the well-known Weber problem, its multi-facility case and angular distance problem. We also analyze a variety of papers related to the literature in order to demonstrate the effectiveness of the review and to get insights for possible research directions. We believe this paper can be used as a complementary and updated version. Research issues which we believe to be worthwhile exploring in future are also highlighted.

4 - Biofuel plant location under an integrated macro and micro perspective

Alexandra Duarte, William Sarache, Yasel Costa

Facility location is a complex decision that must be addressed by integrating two main issues: the production system and supply chain design. The first involves its integration with process decisions and capacity allocation. The second refers to the facility integration in the supply and distribution network structure. Furthermore, a set of quantitative and qualitative factors must be considered in order to improve the decision feasibility. In this sense, the paper proposes an integrated methodology to support the facility location decisions. The methodology frames two fundamental stages: the macro-location and the micro-location. By integrating the supply chain and production system design, the first stage proposes a mathematical optimisation model in order to establish the region (macro-scope) to locate the new plant. The second stage is supported by a multicriteria technique that aggregates a set of qualitative factors allowing the final location decision (micro-scope). A biodiesel plant location, in Colombia, has been examined based on the proposed methodology. After applying the aforementioned stages, a suitable location solution (state and city) was obtained. Based on the experimental results, the projected biodiesel final price is competitive against the current internal market. Also, economic, environmental and social factors were analysed in the final decision. Finally, the proposed solution seems to be economically, environmentally and socially feasible.

■ TB-49

Tuesday, 10:30-12:00 - Graham Hills GH511, Level 5

Airport Operations

Stream: Airport Operations and Airline Scheduling
Invited session
Chair: *Daniel Karapetyan*
Chair: *Jason Atkin*

1 - A Generic Model for Baggage Handling at Airports

Rainer Kolisch, Markus Frey, Ferdinand Kiermaier

We present a generic model for the optimization of the four main baggage handling processes at airports: check-in, outbound, transfer and inbound baggage. Distinctive features of the model are the determination of start times and modes for jobs, flow constraints for bags as well as a unique modeling of the allocation of resources to jobs. We adapt the model for each of the baggage processes.

2 - Optimal Dynamic Allocation of Airport Check-in Resources

Maurizio Tomasella, Duncan McFarlane, Alan Thorne

Check-in/bag drop is the first point of contact between the air traveller and the airline, and often the first point of contact with the airport. Getting check-in/bag drop right is key for the airport, the airline, and the handling agent, which often controls/executes the process on behalf of the airline. Long queues and overcrowded check-in concourses are the first steps to widespread passenger dissatisfaction. In the past decade, a number of OR models have been developed to help airports to better allocate their check-in resources (i.e. desks/kiosks) to airlines/handling agents. However, adoption of these scheduling models is far from widespread, and check-in resource allocation is still carried out based on rules of thumb, with poor results. We argue that existing models may have failed to address the core issues of a process that is: non value-added to the airport operator (e.g. compared to airside retail), key to the airline, but often controlled by a subcontractor. Using Integer Linear Programming, we demonstrate that novel, though simple and inexpensive, resource-sharing policies would allow improved passengers throughput and resource utilisation. We will discuss removal of the most likely barriers to adoption, particularly of the 'desk-sharing' approach we present. We will also discuss computational limitations of some of the existing models, particularly those jointly adopting Dynamic Programming/Queueing Theory, and propose ways forward.

3 - Solving the Monthly Aircrew Pairing Problem via Dynamic Constraint Aggregation

Mohammed Saddoune, Francois Soumis

The monthly crew pairing problem involves determining a minimum-cost set of feasible pairings such that each flight is covered exactly once and side constraints are satisfied. Given its high complexity, this problem is traditionally decomposed into three problems (daily, weekly, and monthly) that are solved sequentially. Recently, Saddoune et al. (2013) showed that the rolling-horizon heuristic produced better solutions than the three-phase approach. For flexibility and to take into account some special features of the planning, flight schedules have recently become less regular. In this context, this paper shows that solving the monthly crew pairing problem globally using an exact method based on dynamic constraint aggregation produces solutions that are cheaper and more robust. Our tests are based on real data provided by a major airline, and they show promising savings of around 1.9% in cost and 36% in idle time compared to those obtained by the rolling-horizon approach of Saddoune et al. (2013).

■ TB-50

Tuesday, 10:30-12:00 - Graham Hills GH512, Level 5

Maritime Transportation 1

Stream: Maritime Transportation
Invited session
Chair: *Kjetil Fagerholt*

1 - Optimization of the Annual Delivery Plan of Rich LNG

Sara Al-Haidous, Mohamed Haouari

We investigate the problem of designing an optimal Annual delivery Plan (ADP) for the Rich LNG. This problem arises at a Qatari company that is considered as a leader in the LNG world market. The problem requires to determine the long-term cargoes delivery dates and the assignment of the vessels to the cargoes, while accommodating several constraints including berth, liquefaction terminal inventory, and bunkering constraints. Two objectives are successively considered: minimizing the vessel fleet and minimizing the deviations with respect to the specified (soft) time windows. We describe a valid MIP formulation and present the results of computational experiments that were carried out on real data.

■ TB-51

Tuesday, 10:30-12:00 - Graham Hills GH542, Level 5

MAI: One-to-one mentoring for practitioners

Stream: Making An Impact 2 (MAI 2)
Invited session
Chair: *Rosemary Byde*

1 - One-to-one mentoring for practitioners

In this session, you can receive 20 minutes of one-to-one mentoring with an experienced practitioner, on issues you may be facing in your practice, career or development. Possible issues may include: Managing your development and career ● Switching sectors ● Changing jobs ● Transitioning from technical 'doer' to managing technical teams ● Finding the right mentor ● Making contacts, building a network ● Getting recognition when you're a technical expert ● Writing a good CV and doing well in interviews

Managing your team ● Recruiting, training, rewarding and retaining the right people ● Making sure your modellers spend their time modelling ● Delegating without tears ● Inspiring others

Making more of an impact ● Selling your services ● Communicating technical results ● Influencing non technical people ● Getting projects implemented

To get the most from the session, you should do some preparation in advance: ● Think about a problem you'd like help and advice on ● What would you like to know from your mentor? ● Expect to ask questions ● Show an interest in your mentor.

This session is only available to people who have signed up in advance via the 'Making an Impact' (MAI) desk. It is one of three similar sessions.

■ TB-52

Tuesday, 10:30-12:00 - Graham Hills GH554, Level 5

OR in Finance and Emerging Markets

Stream: Financial Mathematics and OR
Invited session
Chair: *Nina Kajiji*
Chair: *Gordon Dash*
Chair: *Gerhard-Wilhelm Weber*

1 - Network-Centric Exchange Rate Misalignment Modeling for Detecting Arbitrage Opportunities
Uttam Sarkar, *Abhinay Puvvala*, *Abhishek Chakraborty*

Arbitrage opportunities by means of overseas fixed-term deposits often get paved by lack of synchronization between exchange rates and bank interest rates. Per the ideal theory of Law of Interest Rate Parity and Law of One Price such risk-free returns should not exist. In reality, in the short run in particular, markets do not remain ideally integrated and there exist disparities involving the exchange rates of currencies that provide arbitrage opportunities to dwell in profit prospects. Study of this reality inherently involves interactions of multiple currency exchange rates and is not amenable to a closed form mathematical analysis except under over-simplified assumptions. In this paper, a modeling technique based on computational network analysis has been proposed for capturing the complex pattern of exchange rate misalignments involving multiple currencies. An exchange rate misalignment network has been defined and associated metrics have been proposed to quantify the presence of exchange rate misalignment. Modeling and analysis of exchange rate data from the year 2001 to 2012 expose and showcase counter-intuitive misalignments that existed in reality. ANOVA findings show significance of results. The proposed method is computationally simple, scalable, easy to interpret, and can quantify the relative attractiveness of currencies for investment in the foreign exchange market based on publicly available data on foreign exchange and bank interest rates worldwide.

2 - ESG Portfolio Optimization Based on the Latent Dimensions within Thomson Reuters Corporate Responsibility Indices
Gordon Dash, *Nina Kajiji*

There is an increasing recognition that long-term investment advantages are evidenced by investors who explicitly consider environmental, sustainability and governance factors (ESG factors) in the portfolio diversification process. Despite the investment communities increased reliance on ESG factors a debate on how best to compute a uniform and statistically independent set ESG factors. This research proposes an after-market factor- and machine-computing methodology to create an independent set of ESG factors from the Thomson Reuters US Large Cap Corporate Responsibility Ratings ESG Portfolio that are amenable to inclusion in mean-variance portfolio optimization models. We present ESG efficient sets derived from the mean-variance model, the single- and multiple-index Sharpe model against those derived from the published ESG rankings. These efficient sets are compared to an alternate set obtained from the ESG factor-optimized structure. ANCOVA and MANOVA models based on risk and return portfolio descriptors and the application of a post Bonferroni multiple comparison test provides evidence of a near equivalence between the traditional mean-variance efficient set and the diversified portfolios produced by latent factor optimization. These findings are significant for model builders who seek to employ multiple index models that fully utilize ESG latent returns.

3 - Estimating the impact of social network participation on retail traders
John Forman, *Joanne Horton*

This research examines whether individual FX traders benefit by joining a large social network platform. From an informational sharing perspective, the expectation would be to the affirmative, but that assumes the transmission of non-public information through the network.

What if no such information is present? This matter is addressed by analysing nearly five years of transactional and performance data for members of an online global retail foreign exchange trader social network where trades, positions, and returns were shared in real time with "friends' and beyond. The nature of the participants in such a network argues against the existence of any meaningful amount of non-public information (if any at all), providing the opportunity to study potential "social' membership effects. The existence of such effects are in part tested by estimating a member's connectivity be employing network positions used in the social capital literature. Our findings suggest that there is indeed a social (meaning negative) impact to network membership, one which perhaps surprisingly is felt strongest by traders presumably more knowledgeable and sophisticated than others.

■ TB-53

Tuesday, 10:30-12:00 - Graham Hills GH614, Level 6

Applications of Dynamical Models 1

Stream: Applications of Dynamical Models
Invited session
Chair: *Alberto Pinto*
Chair: *João Almeida*

1 - On the length of the land frontier between Portugal and Spain
João Almeida, *Alberto Pinto*

The land frontier between Portugal and Spain is one of the oldest and longest in Europe. In 1961 L.F. Richardson published a paper entitled "The Problem of Contiguity: An Appendix to 'Statistics of Deadly Quarrels", where he tackled the problem of determining the real length of coastlines or geographical borders between two countries. Noting that in many cases neighbour countries didn't agree about the length of their common frontier, he showed that the length of a coastline or a land frontier depended upon the yardstick or scale with which this length was measured. This prevalent phenomenon is commonly referred to as the 'Richardson effect'. In his paper, Richardson also derived a log-linear relationship between length and scale and this log-log scatter plot of perimeter lengths versus scale intervals came to be known as a 'Richardson plot'. In late 60s, Mandelbrot related the Richardson effect with fractal geometry, this way unvealing the fractal dimension of coastlines and land frontiers. Here we analyse the discrepancy in the lenght of the land frontier between Portugal and Spain, as claimed by each country, under the 'Richardson effect'.

2 - Stochastic Portfolio Optimization of UK Electricity Market
Gerhard-Wilhelm Weber, *Miray Hanim Yildirim*

Countries aim to create economically efficient electricity generation portfolios considering two basic energy security indicators - affordability and availability - while preventing any shortage. However, due to uncertainties both in supply and demand, stochastic optimization techniques are often required in creating the portfolio. In this study, a stochastic and simulation based method, which utilized Ornstein Uhlenbeck mean-reverting process and Monte-Carlo simulations, is presented. The methodology involves generation of stochastic supply curves for different scenarios by considering the power-generation techniques. Here, the supply curves are constructed as piecewise linear functions and market prices are determined by considering electricity production costs, electricity demand, natural gas prices, exchange rates, and generator types. The scenarios are incorporated in a stochastic mixed-integer portfolio optimization model to maximize the profit and to obtain the most economic diversity of energy resources. The performance of the method is tested by using United Kingdom electricity market data.

3 - Economics of Microgrids under uncertainty
Kevin Milis, *Johan Springael*, *Herbert Peremans*

In this paper we present an economical simulation model for a microgrid connected to the general electricity grid, simulating the total operating cost over one year in the presence of uncertain future grid electricity prices, daily electrical load and intermittent generation. Our simulation model consists of five model components: the first of which being the consumption block. The second component models an intermittent electricity source, while the third corresponds to local dispatchable power. The fourth component the electrical storage, while the final

component is the connection to the general electrical grid. Grid electricity prices, hourly load and hourly intermittent generation are exogenous variables and derived from existing datasets. Based upon forecasts made using predictive modelling techniques, we optimize the unit dispatch of generation and storage components connected to the micro gird with regards to yearly operating cost. We present results comparing the operating costs incurred using the predictive models under uncertainty to those incurred in case of full knowledge of future conditions. Additionally, we compare the performance of our optimization to three predetermined storage use strategies for varying levels of grid reliability. The resulting cost patterns are analyzed for different levels of grid reliability using Monte Carlo Methods.

■ TB-54

Tuesday, 10:30-12:00 - Graham Hills GH617, Level 6

System Dynamics Session 2

Stream: System Dynamics Modeling and Simulation
Invited session
Chair: *Erik Larsen*

1 - How to Model Queues: Behavioral Approaches
Erik Larsen, Ann van Ackere, Santiago Arango

In recent years there has been increasing focus on the behavioral aspect in many disciplines, queuing being one of them. There are various methodologies that enable incorporating behavioral issues in queuing models. The choice of method will be driven by the emphasis of the study (repeated customers, information diffusion, reputation building etc.) and the level at which these phenomena are being studied. We compare three different approaches to studying behavioral queuing problems, system dynamics, agent based modeling and experimental methods. These approaches differ mainly in the level at which they address the problem ranging from micro to macro. We identify the comparative advantages for each method and discuss the context in which each method is most appropriate. We also address the complementarity of these different methods. For instance experimental method can be used to validate insights derived from system dynamics and agent based models.

2 - Biogas Plant Operation after the Expiration of Incentive Programmes — A System Dynamics Approach
Yvonne Beck, Axel Löffler

Since 2012, the German incentive strategy to support biogas as renewable energy has shifted from guaranteed feed-in tariffs to subsidized direct marketing. For plants constructed before the last subsidy revision in 2014, switching to direct marketing is optional. As the market integration structure is not yet fully established, risk-averse operators, mainly farmers, hesitate to choose this option. Similar to feed-in tariffs, subsidies for direct marketing are guaranteed for 20 years after the start-up of the plant. In the current system of market integration, due to electricity market prices far below production costs, the operation of biogas plants beyond the subsidy period, which approaches in 2020 for the first plants installed, appears unprofitable.

Based on interviews with experts from the biogas sector, which reveal that economic efficiency is crucial and that confidence in the German subsidy scheme is decreasing, a System Dynamics model is established to explore the operators' decision making processes: In the model, their profit of biogas production beyond subsidy is compared to a substitute strategy of shutting down the plant and investing in a dairy cattle farm with agricultural subsidies.

Scenario analyses show that new incentives are required to make long-term biogas plant operation economically efficient compared to substitute investments such as cattle farming.

3 - An Experimental Investigation of the Impact of the Dynamics of Strategy Maps on Managerial Performance
Ulrike Leopold-Wildburger, Bo Hu, Jürgen Strohhecker

We describe a behavioral based research for testing some hypotheses on the influence of performance improvement by balance BSC (Balanced Scorecard). We apply system dynamics in a twofold way. Firstly, the experimental environment is implemented as a system dynamics simulation during which the participants have the possibility

to adjust the parameters to achieve the best performance. Secondly and more importantly, using system dynamics methodology the participant's task is designed as a manual closed-loop control task. We run experiments with three different treatments: a plain business report cockpit, a BSC cockpit and a strategy map cockpit. They provide different insights into the relationships between the various indicators of the system. We hypothesize that the different cockpits are able to support by different degrees the strategy implementing decisions to be made. We are able to show that the way that performance measures are presented to decision makers makes a significant difference. We discuss the experimental results.

■ TB-55

Tuesday, 10:30-12:00 - Graham Hills GH626, Level 6

Numerical and Simulation Methods in Finance 2

Stream: Numerical and Simulation Methods in Finance
Invited session
Chair: *Aysegul Iscanoglu Cekic*
Chair: *Emel Savku*

1 - An Approximate Long-Memory Range-Based Approach for Value at Risk Estimation
Xiaochun Meng

This paper proposes some approximate long-memory VaR models that incorporate intra-day price ranges. These approaches incorporate lagged intra-day range with the feature of considering different range components calculated over different time horizons. Model estimation is performed using linear quantile regression. We also investigate the impact of the market overnight return on the VaR forecasts. An empirical analysis is conducted on 19 market indices. In spite of the simplicity of the proposed methods, the empirical results show that these models successfully capture the main features of the financial returns and are competitive with established benchmark methods. The empirical results show that some proposed range-based VaR models, utilizing both the intra-day range and the overnight returns, are able to outperform GARCH-based methods and CAViaR models. A combining model of a range-based CAViaR model and one of our newly proposed approximate long-memory model performs the best.

2 - Investment Decisions and Capacity Planning of Battery Technology for Electric Vehicles: The Role of Uncertainty in the Product Life Cycle
Stefan Kupfer, Karsten Kieckhäfer, Elmar Lukas, Thomas Spengler

Electric vehicles play a decisive role in the strategies of the automotive industry. Since the battery accounts for the highest share of value creation in electric vehicles, make or buy decisions for a specific battery technology are crucial investment decisions for car manufacturers. The optimal installed capacity for the production depends on the estimated demand for the new product and thus the estimated cash flows. Empirical research indicates that the sales of innovations typically follow a product life cycle in many industries. Due to cash flows which depend on uncertain future market conditions as well as high investment expenditures, the company has to decide carefully how much capacity it wants to provide for the production. This paper studies the effect of uncertainty on the decision to invest in production capacity for traction batteries for electric vehicles, taking into account the combined effects of flexible investment timing and product life cycle depended sales commonly neglected in the finance and operations research literature. The drift parameter of a geometric Brownian motion is parameterized to an uncertain product life cycle. The investment option is valued numerically with the Crank-Nicholson method. We find that the optimal investment threshold follows an S-curve and derive the optimal capacity choice for the given investment decision. The results indicate that traditional investment valuation approaches lead to false investment recommendations.

3 - Sensitivity Analysis of Expected Paid/Unpaid Overdue Receivables Using Markov Chain Model — SME Case Study
Ladislav Lukas

The paper uses existing Markov chain theory to estimate expected paid/unpaid overdue receivables, and is focused mainly upon sensitivity analysis of calculated estimations. Since such calculations depend upon fundamental matrix of absorption Markov chain chosen, the particularly important role plays data and algorithm for its composition. As a case study, we selected a SME ranged company which provided us its accounting records with payment patterns details related receivables. First, the available data are sorted to extract overdue receivables, which serve to estimate transition probability matrices of absorption Markov chain having several transient states and two absorption ones representing paid and unpaid overdue receivables. Based either on number of overdue receivables or their financial volumes we build different transition probability matrices. The sensitivity analysis of expected paid/unpaid overdue receivables concerns influence of different overdue threshold and tolerance accepted, conditional probabilities between transient and absorption states, as well as distribution of financial volumes in particular transient states registered. The results are discussed in detail showing their practical importance in financial management and providing deeper insight into overdue payment processes thus contributing to risk management, too. All computations and graphical issues are performed by sw Mathematica.

4 - The Use of Neural Networks to Understand Nonlinear Mean Reversion
E. Dante Suarez

We propose the use of Neural Networks (NN) for understanding the mean reversion dynamics. The approach graphically describes cointegrated time series that exhibit nonlinear mean reversion, such as those stemming from equilibrium relationships that are affected by transaction costs or institutional rigidities. NN can thus be useful for understanding the time series resulting from any arbitraged-enforced equilibrium, allowing the researcher to choose the most appropriate description with either a Threshold Autoregression (TAR) or a model such as the Smooth Transition Autoregression (STAR). Our case study is involved with understanding the nature of cross-listed stocks (ADRs) through an analysis of the degree of market integration reflected by the intradaily price discrepancies of cross-listed French, Mexican and American stocks. Our work provides a description of the arbitrage forces that maintain the Law of One Price in these ADR markets, thereby providing a more explicit insight on how these markets are integrated.

■ TB-61
Tuesday, 10:30-12:00 - Graham Hills GH816, Level 8

Emergency Transportation Logistics

Stream: Routing II - Emerging Applications
Invited session
Chair: *Elise Miller-Hooks*

1 - Aging-focused Accessibility Assessment of Multi-modal Facilities towards Better Decision Making in Emergency Transportation Logistics
Eren Ozguven, Hidayet Ozel, Ayberk Kocatepe, Mehmet Baran Ulak

Providing accessibility to the multi-modal facilities in the context of emergency transportation logistics is a critical and complex task that depends on the characteristics of the available transportation infrastructure as well as the population, disaster and region characteristics. This problem becomes even more challenging when aging populations are considered since any extra time incurred for the aging can be especially dangerous in light of health and other safety concerns, especially during emergency evacuations. This clearly indicates the need for state/federal emergency transportation plans to have a multi-modal transportation assessment component that specifically focuses on aging people. This paper presents a timely accessibility assessment of the multi-modal transportation facilities such as airports followed by the development of an extensive aging-focused and Geographic Information Systems (GIS)-based emergency knowledge base. This analysis is supported by an evaluation of the significant factors that influence the accessibility of multi-modal transportation facilities during emergencies. Finally, aging-focused travel time reliability/accessibility measures and route optimization models are created, which aim to maximize the accessibility to the multi-modal transportation facilities for the aging. The knowledge gained from the results of this research

will successfully contribute to the development of more reliable aging-focused emergency transportation plans.

2 - Multi stage evacuation management under uncertainty: a stochastic programming approach
Suleyman Karabuk, Hasan Manzour

We consider evacuation in the face of fast moving hazardous weather events such as tornadoes, where there is a high degree of directional uncertainty that evolves in stages throughout the evacuation period. To describe the problem, we formulate a multistage stochastic programming model with recourse, which relies on weather forecasts of varying levels of information, and generates an evacuation plan that is hedged against uncertainty. We analyze characteristics of optimal evacuation plans under several factors of interest.

3 - Transportation System Resilience given Interdependencies with Power Systems
Elise Miller-Hooks, Seksun Moryadee, Hossein Fotouhi, Steven Gabriel, Neza Vodopivec

A transportation network is a critical lifeline for a community, essential to the functioning of society and the viability of the economy. The wellbeing of the community's members depends on their mobility, ability to move goods, and access to services. Having a resilient transportation infrastructure system that performs well under multiple hazard situations is critical to a community. A transportation system is a complex, multi-modal system consisting, among other modes, of rail, highway, air, and maritime networks, and ports or other intermodal connections which link such networks. Moreover, transportation networks are inherently interdependent with other critical lifelines, including power, telecommunications, water, sanitation, and building infrastructure networks, which are themselves complex systems. We present techniques for quantifying a transportation system's resilience given such interdependencies. We focus this presentation on the interdependencies with power systems.

■ TB-62
Tuesday, 10:30-12:00 - Livingstone LT203, Level 2

Operations Research 6

Stream: Operations Research, other
Contributed session
Chair: *M Reza Abdi*

1 - A Factorial Design Approach for Supporting Nutrition Policy on Single-Person Households
Kiyeon Kang, So Young Sohn

As an increase in the number of single-person households is a current global trend, a study supporting nutrition policy for single-person households is needed. This paper presents a factorial design approach for extracting poorly nourished groups in single-person households. We use the data of 17,394 adults who participated in the 2010—2012 Korea National Health and Nutrition Examination Survey. First, we reduce the dimension of nutrient intake attributes via factor analysis. The factorial design is then used to reveal the interactions among geodemographic factors with respect to individual nutrient intake pattern. The poorly nourished groups in single-person households are then identified and proper nutrition policies are suggested.

2 - Reconfigurable Manufacturing Systems and Risks in Supply Chain Tiers
M Reza Abdi, Farideh Delavari Edalat

The paper investigates the risk sources in a supply chain consisting of a reconfigurable manufacturing system (RMS). The risk factors in a the supply chain are indicated and classified into different categories such as supply risks, demand risks, catastrophic risks, infrastructure and regulatory risks, and bureaucratic and legal risks. An analytical hierarchical process (AHP) Model is proposed to evaluate the risk elements with respect to key criteria such as the risk impact and the likelihood of occurrence with consideration of the data consistency. The model input data is collected through a questionnaire survey and semi-structured interviews conducted with ten supply chain and manufacturing experts in the UK. The RMS resilient against the risk impacts is examined by means of the RMS characteristics such as manufacturing

capacity adjustment, manufacturing reconfigurability, and responsiveness to the market changes. The paper explores the necessity of a continuous linkage between market demand and manufacturing capacity in an RMS in order to reduce the bullwhip and to optimise the capacity usage. It is verified the RMS is resilient for handling the most of the demand-side risks, either directly or indirectly whereas the system design distinguishing features are still vulnerable against external risks, mainly caused by the supply side, the infrastructure environment, and the regulatory and bureaucratic aspects.

3 - Factors influencing consumer's strategic saving behavior - data analysis based on the Internet
Jingjing Wu

This paper first defines customers purchase saving and proposes measures to estimate consumer saving from strategic behavior. It then suggests a theoretical framework to examine factors that influence such consumer saving. Based on 67,530 price observations of 230 products from 53 sellers, we give a descriptive analysis of consumer saving from strategic behavior and estimate relevant factors accordingly. The results reveal that consumer saving from strategic behavior has a positive relationship with price level. Consumers can also expect a higher level of saving from strategic behavior when purchasing from sellers who show advantages over others on size, service, fake compensation commitment, and website ranking. Furthermore, the display time of product influences consumer saving from strategic behavior. Overall, we examine consumer saving from strategic behavior empirically from consumer perspective, which provides a new theoretical approach and practical guidelines for understanding consumer's strategic behavior.

■ TB-66

Tuesday, 10:30-12:00 - Livingstone LT209, Level 2

Routing 1

Stream: Optimization
Invited session
Chair: *Juan José Salazar González*

1 - Subtour Elimination Constraints for TSP with Sparse Distance Matrix
Aydin Sipahioglu

Travelling Salesman Problem (TSP) is one of the most well-known and studied NP-hard problems in OR. The key point of the solution procedure is to eliminate subtours. There are different subtour elimination constraints in the literature for TSP. Most of these constraints can be used with complete or sparse distance matrix. Besides, a sparse distance matrix can be converted to a complete matrix by determining the shortest path between nodes. However, it is possible to obtain tight formulation to eliminate subtours by using the structure of sparse matrix. In this study, new subtour elimination constraints based on MTZ are offered for TSP and m-TSP with sparse distance matrix. The developed constraints are tested on some instances and the results are also given.

2 - On Solving the Capacitated Vehicle Routing Problem by Branch-and-Price
Farah Zeghal Mansour, Mohamed Haouari

We address the capacitated vehicle routing problem (CVRP). This hard combinatorial optimization problem requires building a minimum-cost set of routes for a homogenous fleet of capacitated vehicles so as to deliver the demands to a set of scattered customers. The CVRP is formulated as a set covering problem and solved using a Branch-and-Price (B&P) approach. A first distinctive feature of our B&P is that the pricing problem generates elementary routes by solving a resource constrained shortest path problem (ERCSSP) that is formulated as a mixed-integer linear program. Also, to mitigate the slow tail-end convergence of the column generation procedure, we implemented stabilization strategies that require solving quadratic linear programs. A third distinctive feature of our approach is that the branching is achieved on the route variables instead of the usual arc variables. We present the results of preliminary experiments that were carried out on two sets of symmetric and asymmetric benchmark instances.

3 - A New Mathematical Programming Formulation for the Picker Routing Problem
André Scholz, Sebastian Henn, Gerhard Wäscher

The picker routing problem deals with the determination of sequences according to which articles have to be picked in the picking area of a distribution warehouse and the identification of the corresponding paths which have to be travelled by human operators (order pickers). The picking area typically possesses a block layout, i.e. the articles are located in parallel picking aisles, and the order pickers can only change over to another picking aisle at certain positions by means of so-called cross aisles. Due to this specific property, the picker routing problem represents a special case of the classic traveling salesman problem (TSP). In this presentation, for the first time a mathematical programming formulation is proposed which takes into account the specific property. Based on extensive numerical experiments, it is shown that the proposed formulation is superior to standard TSP formulations.

4 - The split-demand one-commodity pickup-and-delivery travelling salesman problem
Juan José Salazar González, Beatriz Santos Hernandez

This paper introduces a new vehicle routing problem transferring one commodity between customers with a capacitated vehicle that can visit a customer more than once, although a maximum number of visits must be respected. It generalizes the capacitated vehicle routing problem with split demands and some other variants recently addressed in the literature. We model the problem with a single commodity flow formulation and design a branch-and-cut approach to solve it. We make use of Benders Decomposition to project out the flow variables from the formulation. Inequalities to strengthen the linear programming relaxation are also presented and separated within the approach. Extensive computational results illustrate the performance of the approach on benchmark instances from the literature. This article has been recently accepted for publication in "Transportation Research B".

■ TB-67

Tuesday, 10:30-12:00 - Livingstone LT210, Level 2

Applications of Combinatorial Optimization

Stream: Combinatorial Optimization
Invited session
Chair: *Jan van Vuuren*

1 - Tri-Objective Generator Maintenance Scheduling for a National Power Utility's Energy Flow Simulator
Berndt Lindner, Jan van Vuuren

Generator Maintenance Scheduling (GMS) is a critical assignment problem for power utilities. In this problem multiple objectives exist, including maximising reliability (levelling the reserve margins over time), reducing maintenance and production costs and minimising the risk of breakdowns. Popular operations research techniques used to solve this problem include integer programming and a variety of meta-heuristics. In this talk, it will be demonstrated how simulated annealing may be used to solve a bi-objective version of the GMS problem approximately. This solution approach will be incorporated into the energy flow simulator of the South African national power utility in order to facilitate an analysis involving what-if scenarios planning for the utility's entire supply chain, from coal delivery, to generation, to transmission and finally onto consumers. This Monte-Carlo simulator has four consecutive modules, namely consumption, production planning, coal stockpile management and generation. The GMS solutions will be provided as input to the production planning module, which uses linear programming to schedule the amount of energy per power station so as to attempt meeting daily expected demand efficiently. The output of this module will then inform in a feedback-fashion the second objective to be included in the GMS model, namely to minimise the production cost. Future work will include incorporation of a third objective, namely minimising the risk of unplanned outages.

2 - A Weapon Assignment Subsystem as Real-Time Decision Support in a Ground-Based Air Defence Environment
Daniel Lotter

In this paper, a weapon assignment system architecture is put forward for use by fire control officers in a military environment as real-time decision support. Detailed descriptions of the various substructures contained within such a system as well as corresponding processes central to the effective functioning of the system are discussed. In addition, a multi-objective dynamic weapon assignment model is proposed for inclusion in the weapon assignment model component and the working thereof is illustrated by solving it in the context of a simulated ground-based air defence environment.

3 - The Design of a Threat Evaluation and Weapon Assignment System Performance Evaluator
Louw Truter, Jan van Vuuren

One of the difficulties associated with defending friendly assets in a ground-based air defence scenario is determining the optimal allocation of available resources, such as ground weapon systems, sensor systems and ammunition, to counter aerial threats. Before this resource allocation can be optimised, it is necessary to estimate the level of threat posed by each aerial vehicle. A fire control officer, who is responsible for both these decision processes, is usually supported by a Threat Evaluation and Weapon Assignment (TEWA) decision support system. Such a system is responsible for prioritising airborne threats according to the level of danger they pose to defended assets, and consequently using these threat values to propose high-quality assignments of ground-based resources to these threats. These resources are typically allocated to minimize the survival probability of the airborne threats. Different solution methodologies to the weapon assignment process and the threat evaluation process are available in the literature, but these methodologies have not been assessed collectively in the open literature. A novel simulation-based performance evaluation framework is proposed in this talk for evaluating the performance of various existing threat evaluation and weapon assignment algorithms in conjunction with each other.

4 - An Agent-Based Model for Simulating the Population Dynamics of Eldana Saccharina Walker
Brian van Vuuren, Linke Potgieter, Jan van Vuuren

Eldana saccharina Walker (Lepidoptera: Pyralidae) is a stalk borer pest which feeds on internal tissue of sugarcane stalks, causing yield losses in sucrose. Various control methods have been proposed in the literature in an attempt to suppress the pest. These solution methods are, however, often difficult and costly to test, implement and develop further in an iterative manner. It is proposed that an agent-based simulation model be developed which accurately simulates the stalk borer's biology, feeding habits, mating behaviour, dispersal patters and various other characteristics so as to better understand the behaviour and population dynamics of E. saccharina. In particular, E. saccharina's complex mating procedure requires careful consideration and structural implementation in the model as this procedure plays a primary role in the continued prevalence of the pest. Once a well-calibrated simulation model, which incorporates the natural variation of an ecological system, has been designed, certain control strategies can be developed and tested using the model prior to in-field implementation, in the hope of minimising cost and assisting in the ongoing development of an integrated pest management (IPM) system. The modelling framework for a novel, agent-based model of E. saccharina will be presented in this talk, together with detail on the modelling approach adopted to incorporate some of the biological attributes of the pest.

■ TB-69
Tuesday, 10:30-12:00 - Livingstone LT212, Level 2

Data Mining, Statistics Theory and Its Applications

Stream: Computational Statistics
Invited session
Chair: *Pakize Taylan*

1 - Prediction of Bank Failures via Machine Learning Techniques using Pooled Panel Financial Data
Birsen Eygi Erdogan, Erol Egrioglu, Esra Akdeniz Duran

Most of the financial crises start with the collapse of the banks. Sometimes the bankruptcy of just one bank may make a domino effect to the whole economy of a country. That is why it is very important to prescience the failure of the banks operating in the financial system. In this study it is aimed to develop an early warning system for Turkish commercial banks failure using longitudinal financial ratios. The data is analyzed using Multiplicative Neuron Model Neural Network and Support Vector Machines for pooled panel data. The success status of the banks was used as the dependent variable and financial ratios were used as independent variables. For the comparison of the modelling performances the classification measures are used.

2 - Semi-supervised Clustering with Regional Data Objects
Derya Dinler, Mustafa Kemal Tural

In this study, we address the problem of clustering regional data objects in the presence of prior knowledge. We assume that prior knowledge can be available in the form of labeled data and/or instance level constraints. We aim to find a partition of the data objects that minimizes the sum of squares of the maximum (Euclidean) distances of the regional data objects to the cluster centers they are assigned to considering at the same time the prior knowledge. For the problem, we propose a semi—supervised clustering algorithm that uses the framework of k-means algorithm which is the most famous partitional clustering algorithm. Experimental studies show that the proposed algorithm is promising.

3 - A Projection Multi-objective SVM Method for Multi-class Classification
Ling Liu, Belen Martin Barragan, Francisco Prieto

Support Vector Machines (SVMs) have been successfully used for classifications of two classes. For multi-class classifications, various single-objective SVMs have been introduced mostly based on two families of methods: an all-together approach and a combination of binary classifications. Most of these single-objective SVMs consider neither the different costs of different misclassifications nor the users' preferences. To overcome these drawbacks, some multi-objective SVMs have been introduced. By solving large- scale second-order cone programs (SOCPs), these multi-objective SVMs give us weakly Pareto-optimal solutions. When we have many classes to classify, solving the SOCPs becomes expensive. We propose the Projected Multi-objective SVM (PM), which works in a higher dimensional space than the object space. We characterize the Pareto-optimal solutions of PM based on the optimal solution of a quadratic program (QP). When there are many classes to classify, we can easily get the Pareto-optimal solutions of PM because the QP can be decomposed into smaller QPs. Our experiments indicate that PM gives us the best classification accuracies and least training time compared with other approaches. In addition, we use some Pareto compliant indicators to evaluate the approximation performances of the multi-objective approaches. It shows that PM provides the best approximation in nearly all cases. We conclude that PM is an efficient and effective method for multi-class classifications.

■ TB-70
Tuesday, 10:30-12:00 - Livingstone LT303, Level 3

Intelligent Systems in Economics and Finance

Stream: Information and Intelligent Systems
Invited session
Chair: *Gerhard-Wilhelm Weber*
Chair: *Roman Senkerik*

1 - Forecasting of Intermediate Goods Index and Capital Goods Index of Turkey
Cansu Aksu, M. Fatih Bayramoglu

Production of intermediate goods and capital goods is one of the building blocks of industrial production. Although Turkey has made major strides in production of both intermediate and capital goods during the past decade, it still imports most of its requirements in these two product categories. Therefore, accurate forecasting of Intermediate Goods Index and Capital Goods Index, which are two important macroeconomic indicators, is important. This study monthly forecasts these two indexes for 2014, using the GM(1,1) Rolling Model developed within the Grey Systems Theory. Results indicate that the GM(1,1) model has satisfactory performance in forecasting both series.

2 - Coordinating Content Invest and Seller Participation
Zhong Yao

A growing number of industries nowadays are organized around intermediary platforms which facilitate transactions between sellers and buyers. In recent years, emerging communication technology developments have largely enriched the content for on-platform sales. However, strategies for platform content management are largely unknown because most existing literature on two-sided market typically takes platform's developments of first-party content as given. To fill the gap, this paper employs a game-theoretical model to investigate a two-sided platform's decision-making on both pricing strategies and content management. We provide a comprehensive analysis by examining (1) platform's objective, (2) relationship between platform content and seller participation, and (3) heterogeneity in platform adopters' valuation towards platform content. Our results suggest that platform's optimal strategies are significantly influenced by adopter heterogeneity and platform's objective, while much less sensitive to the relationship between platform content and seller participation. Specifically, when adopters receive heterogenous benefits from platform content, the private platform's strategies are independent from each other; the public platform cannot be self-sufficient to reach social optimality; the Ramsey platform's strategies are complementary when network effects are strengthen, while substitutable when the cost for developing first-party content increases.

3 - Quantitative Analysis and Forecasting in Internet Banking Channels and Evaluation Methodology for Implemented Strategies
Danai Spilioti, Christina Konstantinidou, Nikoletta Zampeta Legaki, Vasilis Assimakopoulos

As Electronic Banking Channels have experienced a great growth in recent years and are becoming more popular, banking institutions take advantage of this impact, improving the services provided. Thus, it is necessary to develop assessment methodologies and Decision Support Systems for marketing and managerial strategies. In this term, 8.5 million Mobile and 102 million Web Banking transactions by a large Greek banking institution, from 2010 up to 2013, were analyzed in order to identify the relationship between these channels and they are categorized based on users' demographic characteristics. Monthly transactions time series of different user groups were exported and extrapolated using time series forecasting methods in order to produce forecasts for different forecasting horizons using rolling forecasting and evaluate them for each case for both services. Moreover, forecasts were produced respectively, using bottom up and top down forecasting technique investigating the impact on forecasting accuracy in different levels depending on general demographic characteristic. Results indicate that forecasts depended on certain demographics classification are more accurate. Finally, an assessment methodology is proposed in order to evaluate promotion actions aiming at group of users with particular demographic characteristics. For future research could be done an extended investigation of the classification of users and the depiction of the behavior with specific characteristics.

4 - On the Embedding of Chaotic Dynamics into Metaheuristics
Roman Senkerik, Michal Pluhacek

This research deals with the hybridization of the two soft-computing fields, which are the chaos theory and evolutionary computation. This research is aimed at the embed- ding discrete dissipative chaotic systems in the form of chaotic pseudo random number generators for the metaheuristic. From the previous research, it follows that very promising results were obtained through the utilization of different chaotic maps, which have unique properties with connection to evolutionary algorithms. A chaotic approach generally uses the chaotic map directly in the place of a pseudo random number generator. This causes the metaheuristic to map unique regions, since the natural chaotic dynamics iterates to new regions. The concept of chaos driven evolutionary algorithms proved itself to be a powerful in both real and combinatorial problems' domains as well as for higher-dimensional problems. This concept was successfully used in swarm-based and population-based algorithms, such as Differential Evolution, Particle Swarm Optimization algorithm, Bee algorithm, Firefly algorithm and Self Organizing Migration algorithm. Furthermore the direct embedding of chaotic dynamics into the evolutionary/swarm based algorithms is advantageous, since it can be easily implemented as a plug-in module into any existing algorithm or strategy. Also there are no major adjustments in the code required (instead of calling function Rand(), one iteration of chaotic system is taken).

Graphs and Networks B

Stream: Graphs and Networks
Invited session
Chair: *Reinhardt Euler*
Chair: *Tahar Kechadi*

1 - Graph Constructions for the p-Median Problem: A Practical Example from a Road Network
Pascal Rebreyend

Graphs are needed to compute distances in a network. We will present and investigate practical problems faced when rebuilding a graph representing a road network from the official swedish database. This database contains the list of segments representing roads. Identifying crossings is the first step of the process. This is achieved in our case by examining the x,y,z coordinates of the ends of each segment. The different strongly connected components of the graphs are then extracted. A matching with points coming from other sources such as localization of citizens is also done. Then, we can identify real islands from artefacts due to approximations in coordinates. At this stage the graph has still several millions of nodes. Different cleaning processes such as removing useless dead-end roads are explained. Points which are only useful to represent the shape of the road are removed too. The last stage is to build the distance matrix between all candidate nodes. Candidate nodes can be selected according to different criteria. The Dijkstra algorithm with Fibonacci heap as storage structure is used. Cost of computations are presented and possibilities of parallel computing are investigated. At this stage, we will discuss how we can extract from this graph a reasonable amount of candidate points for p-median points. We will also present and discuss available and missing meta-information about the road segments.

2 - Network Value Maximization in Social Networks with Independent Cascade Diffusion Model
Evren Guney

The network value maximization problem (NVMP) is a challenging combinatorial stochastic optimization problem defined on social networks. In this problem, the aim is to identify influential individuals in an online social network so that when selected they can create an influence over their peers and maximize total value generated. The total value generated is defined as the individuals personal value plus the additional value created by his/her social impact. In NVMP, there is a budget limit to recruit or initially activate the selected individuals and each individual has an arbitrary activation cost. Many researchers focused on the speed of the solution procedure which is based on greedy-based heuristic methods. Contrarily, in this study a binary integer program that approximates the original stochastic optimization problem is developed and it is efficiently solved with a Sample Average Approximation (SAA) scheme. The influence spread is simulated by using the independent cascade diffusion model, which is extensively used in the literature. Computational results reveals that SAA method provides better results than the greedy method without worsening the solution time performance. The SAA scheme also provides information about the bounds and optimality gaps on the objective function values, which has been an open question in the literature.

3 - Analysis of cascading failures across interdependent dynamic networks
Nils Goldbeck, Washington Ochieng, Panagiotis Angeloudis

Improving the resilience of urban infrastructure, such as transport, energy and telecommunication networks, is a key aspect of disaster risk management. These networks are interdependent in complex ways and the overall risk has to be assessed from a system-of-systems perspective rather than by looking at individual networks. The theory of complex networks has been instrumental in modelling such interdependent infrastructure systems and identifying conditions for catastrophic cascades of failures. Many of the coupling phenomena, however, cannot be captured with models that consider only connectivity. This paper presents a method that models the transmission of failure across system boundaries using measures that represent the capacity and load at the level of individual network components. This enables a more comprehensive analysis, for example by taking into account the dynamic effects of demand fluctuations, redistribution of network loads and recovery mechanisms.

■ TB-73

Tuesday, 10:30-12:00 - Collins CL205, Level 2

Energy Forecasting

Stream: Forecasting & Time Series Prediction
Invited session
Chair: *Nikolaos Kourentzes*
Chair: *Juan Ramon Trapero Arenas*

1 - Solar irradiation forecasting based on dynamic harmonic regression

Juan Ramon Trapero Arenas, Nikolaos Kourentzes, Alberto Martin

Solar power generation is a crucial research area for countries that have high dependency on fossil energy sources and count on high solar resource potential. In order to integrate the electricity generated by solar power plants into the grid, solar irradiation must be reasonably well forecasted, where deviations of the forecasted value from the actual measured value involve significant costs. The present paper proposes a univariate Dynamic Harmonic Regression model set up in a State Space framework for short-term (1 to 24 hours) solar irradiation forecasting. The DHR is a type of Unobserved Components model that can be considered as an extension of the typical harmonic regression, where the coefficients are time-varying. This method provides a fast automatic identification and estimation procedure based on the frequency domain. Furthermore, the recursive algorithm as the Kalman Filter is employed to yield adaptive predictions. Time series hourly aggregated as the Global Horizontal Irradiation and the Direct Normal Irradiation will be used to illustrate the proposed approach. The good forecasting performance is illustrated with solar irradiance measurements collected from ground-based weather stations located in Spain. The results show that the Dynamic Harmonic Regression achieves a relative Root Mean Squared Error about 30% and 47% for the Global and Direct irradiation components, respectively, for a forecast horizon of 24 hours ahead.

2 - SSpace: a toolbox for all seasons

Marco Antonio Villegas García, Diego José Pedregal Tercero

This paper illustrates the utility of SSpace, a piece of software for the analysis of State Space systems. The toolbox has been available during a number of years, but recently has been enhanced with new capabilities, like exact filtering, smoothing, disturbance smoothing, likelihood estimation, nested systems, system concatenation, non-gaussian and non-linear models, etc. The key advantage of this particular toolbox over other pieces of software is its generality, flexibility, ease of use and the fact that it is available across different platforms (like Matlab, Octave, R, and more to come). Regarding generality, different specifications of the same dynamic system are possible because all system matrices may be time variable, covariances between state and observed noises are allowed, etc. The flexibility comes from the way the user communicates with the computer, since model implementation requires writing a function in which any sort of standard programming is allowed. This may look irrelevant at a first glance, but is a powerful way of implementing models, because it opens up the possibility to some non-linear models, different parameterization of the same models, any sort of constraints among parameters, etc. SSpace is being exploited successfully currently in different applications, ranging from traffic casualties forecasting projects sponsored by the Spanish Traffic General Directorate (DGT in Spanish) and energy forecasting, among others.

3 - Exponential smoothing parameter estimation for complex seasonal forms: the case solar irradiation forecasting

Nikolaos Kourentzes, Juan Ramon Trapero Arenas

Renewable energy generation has become more important over the years, bringing more sustainable options to the energy mix of countries. Solar power generation is one such option. Although solar energy is attractive, it brings new forecasting challenges. In order to integrate solar energy into the grid it is important to predict the energy supply accurately, which is dependent on solar irradiation. Large forecast errors can lead to significant costs for the operator. In this work we investigate the use of exponential smoothing to produce univariate forecasts for solar irradiation. These type of models have been explored in the past, due to their significant operational advantages as they are simple to deploy and use and do not require costly additional inputs as numerical weather models do. However, the forecasting performance

of exponential smoothing has been challenged in the literature. We argue that there are two key reasons for this. First, this is due to the complex seasonal shapes exhibited in solar irradiance data. Second, conventional exponential smoothing parameter estimation is often not capable of identifying good parameters. We explore both issues by investigating the use of alternative optimisation cost functions, relaxing assumptions about the model form, in order to increase short and long term forecasting accuracy. We find that alternative cost functions have substantial benefits in terms of forecasting accuracy, data requirements and computational costs.

4 - Robust designs for diesel fuel surrogate models

Irene García Camacha Gutiérrez, Raúl Martin-Martin

Mixture models are used for analyzing problems where the controlled variables by the experimenter are proportions. The design region turns a constrained region called simplex. Polynomial models have been the most extensively studied in the literature for describing such behaviors. In general, they are appropriate, but no for all mixture systems. We investigate the problem of designing for polynomials models, when the assumed model form is only an approximation to an unknown true model. This approach is based on a notion of the maximum of some scalar-valued function of the mean-squared error matrix of the estimates over a neighborhood of the true model to that which is fitted by the experimenter. For this purpose, it is necessary to develop algorithmic techniques for computing these designs. An improved algorithm based on genetic algorithms is proposed in this work. The selection of the optimal formulation of a diesel surrogate for the prediction of auto-ignition under HCCI engine conditions (J.J. Hernández et al. 2008, Fuel) motivated the procedures provided.

■ TB-77

Tuesday, 10:30-12:00 - Collins Insight Institute

Behavioural issues in OR interventions

Stream: Behavioural Operational Research
Invited session
Chair: *Mike Yearworth*

1 - Towards a dynamic learning perspective of facilitated modelling

Thanos Papadopoulos, Elena Tavella

This research explores how facilitators learn in facilitated modeling (FM). The literature on FM highlights the role of the facilitator, expert or novice, in shaping the FM workshops, and argues for particular characteristics of facilitators concerning the management of the workshop and achievement of outcomes, discusses differences between experts and novices, and how novices can use scripts in order to switch between and combine facilitation skills and competencies to successfully manage FM workshops and achieve outcomes. However, there is little research analysing the process by which individuals learn how to use FM and how they become experts. The literature highlights the challenges related to FM teaching, but does not emphasise learning and does not directly examine how facilitators learn. This lack of understanding of how facilitators learn to use FM approaches in practice affects their development. Drawing on theories and models from management, adult, individual and entrepreneurial learning literature and informed by ongoing empirical work with FM facilitators, this paper proposes new concepts for the study of facilitators' learning and develops a deeper conceptualization of emergent themes within the context of how facilitators learn. Our research contributes to Behavioural Operational Research in that it provides a combination of lenses to study 'learning' that affects the behavior of facilitators within FM.

2 - Understanding the impact of stakeholder behavior in preparing forecasts

Jonathan Malpass

The need to forecast accurately is imperative for any service organization; the associated costs of deploying too many resources or the impact of failing to meet service levels mean that poor forecasts have a direct impact on an organization's bottom line. Very often, however, the individual who is ultimately responsible for forecasts will be driven by certain objectives that conflict with the ability of the forecaster to produce accurate forecasts. By modelling the potential behavior of various stakeholders in the service chain, the impacts of different decisions have been understood and a series of outcomes derived. These

scenarios have been used has been used in BT to help decision makers understand their decision-making process and change aspects of their policies. This paper will present a brief overview of the problems associated with forecasting and describe the process of capturing behavior and the outcomes.

3 - Exploring the behavioural dimension of OR intervention: Variance, process and modelling approaches
L. Alberto Franco, Etienne Rouwette

Most operational researchers would agree that the notion of 'intervention' is central to the theory and practice of OR. Broadly, an OR intervention is concerned with improving a problem situation faced by a client through the design and use of model-based approaches. The question of whether OR interventions can indeed improve a problem a situation can be answered in different ways, and in this presentation we adopt a behavioural lens to address this concern. Drawing upon research into organisational change, we present three approaches to the study of OR interventions -variance, process, and modelling- which provide partial but complementary understandings of the nature OR interventions and their behavioural impacts. We argue that coordinating the pluralistic insights from the three approaches can provide a richer understanding of the behavioural dimension of OR interventions, and offer useful guidance for intervention practice.

4 - The performative idiom and PSMs
Mike Yearworth, Leroy White, Richard Ormerod

Pickering's Mangle of Practice appears to offer a useful construct for the analysis of PSM workshops as well as an inspiration for OR practitioners to produce more informative case studies from their work. Both are promising avenues to pursue for further research into what Pickering labels as the performative idiom of SSK and we encourage this. However, we discuss here a theoretical contribution addressing the question of whether the Mangle offers a similar view to what Checkland called a "phenomenological investigation into the meanings which actors in a situation attribute to the reality they perceive' and thus to an anchoring of SSM in the "philosophical/sociological tradition of interpretive social science'. We present some of these points of correspondence between Checkland's and Pickering's thinking and discuss whether the Mangle and the performative idiom offer a better theoretical perspective for analyzing PSM interventions generally.

■ TB-78

Tuesday, 10:30-12:00 - Architecture AR201, Level 2

Analysis and Design of Markets for Homogeneous Goods

Stream: Mathematical Models in Macro- and Microeconomics
Invited session
Chair: *Alexander Vasin*

1 - Welfare Maximization Problem for Network Markets under Perfect Competition
Ekaterina Daylova, Alexander Vasin

For many markets of homogeneous goods, the network structure determines the efficiency to a large extent. In particular, this is often true for electricity and natural gas markets. We consider network markets under perfect competition and study a total welfare maximization problem, taking into account a benefit of the transmitting system, producers' profits, consumer surpluses, and construction costs of the transmission lines. We examine properties of the competitive equilibrium and the welfare function in regard to transmission capacities and provide methods for computation of their optimal values for several types of network structures.

2 - Optimization of the Network Structure for Chain-type and Tree-type Markets.
Alexander Vasin, Marina Dolmatova, Polina Kartunova

We consider a competitive market consisting of n local markets with given supply and demand functions. Each market i=1,..,n-1 is connected with market i+1 by transmission line. The cost functions of transmission capacity increment include fixed and variable components. We set a problem of the total social welfare optimization for the

model and provide a dynamic programming algorithm that determines the optimal transmission capacities. We generalize this algorithm for tree-type and cyclic network markets, and also for markets with exporting and importing nodes.

3 - Reform in the Russian Power Sector: Achievements and Failures
Sergei Chernavskii

Reforming the Russian power sector was aimed at transforming the state-owned and -governed industry into a market system. Econometric analysis of empiric data has shown no economies of scale if the capacity of generating company is over 3.6 GW. The author shows that at the beginning of the 21th century, when a decision was taken to restructure the power sector and organize a wholesale competitive electricity market, some of the conditions reducing the risk of a successful reforming were absent. In particular, there was lack of capacity of power transmission lines connecting different regions of the country. Moreover, the quality of the institutions contributing to market competition, in particular of a legal system, was insufficient. Also, there was no regulatory reform in the services provided by the existent power transmission natural monopoly. The reform offered power producers possibilities for competition in two price zones: the European part and Siberia. The econometric models used in the paper allow evaluating the function of power generation costs in each of the price zones. The author analyzes short- and long-term risks in the wholesale electricity market and provides measures to lower the risk of retaining competition in the long run.

4 - Studying an Oligopolistic Electricity Market Equilibrium under Network Constraints
Oleg Khamisov, Sergey Podkovalnikov

In our talk we study an oligopolistic model which describes long-term electricity market considering generating capacity expansion under network constraints. Participants of the market are represented by generating companies and we are looking for the Nash-Cournot equilibrium. Each company owns different plants at different nodes of the network. Company strategy is year energy production. Consumers are modeled by a linear year inverse demand function and we explain what ideas were used for constructing this function. Total year generation consists of season working days and weekends generation. If we exclude the net constraints then the model is just an example of the potential game and is reduced to an ordinary convex quadratic optimization problem though of big dimension. Then we check whether it is possible to realize the obtained solution within the previously given network constraints. If not we suggest a procedure for adjustment of the solution to the network keeping in mind that the model is of the long-term type, hence the network can be modernized. Finally we present computational results performed on a part of central energy system of Russia and make some conclusions.

■ TB-79

Tuesday, 10:30-12:00 - Architecture AR310, Level 3

Sport Strategy Optimization

Stream: OR in Sports
Invited session
Chair: *Susanne Börner*

1 - On the duration of a tennis game
Marco Ferrante, Giovanni Fonseca

We present a generalization of previously considered Markovian models for the tennis game that overcome the assumption that the points played are i.i.d. Indeed, we postulate that in any game there are two different situations: the first 6 points and the, possible, additional points after the first deuce, with different winning probabilities. We are able to compute the winning probabilities and the expected duration of a game and a set in this more general framework and we test our results considering 62 matches between Novak Djokovic, Roger Federer and Rafael Nadal.

2 - How to win a Beach Volleyball Match Using Multi-Scale Markov Decision Processes
Susanne Börner

How can your team increase its chances to win a beach volleyball match given your team's skills? What is the impact of having the first serve in a set? Should the next attack be as aggressive as possible? We tackle these kind of strategic questions using two interacting Markov Decisions Problems. An aggregated model is treated analytically, whereas a more detailed model is simulated to calibrate the aggregated model. If actions in the aggregated model are aggressive and timid play, then our method recommends a policy depending on statistics from your team's training sessions and historical observations of the opposing team's skills. These recommendations are even possible if the two teams have never played a real match against each other.

■ TB-80

Tuesday, 10:30-12:00 - Architecture AR311, Level 3

Vehicle Routing - Models and Methods

Stream: Transportation Planning
Invited session
Chair: *Tobias Buer*

1 - A Multi-objective Collaborative Approach for the Travelling Salesman Problem with Time Windows
Christof Defryn, Kenneth Sörensen

The travelling salesman problem with time windows (TSPTW) is an extension of the classical travelling salesman problem where a time window interval is specified for every client. In this work, the TSPTW is extended by embedding it in a collaborative environment, where clients of different partners can be served by a shared fleet of vehicles. This approach gives rise to additional issues. First, the collaborative environment requires that a cost allocation method is embedded within our solution method. In this way, the total coalition cost can be allocated to the individual partners, which allows to give incentives and reward flexibility. The Shapley Value allocation method is selected, as this is considered a relevant method both in academics and industry. The inclusion of such a cost allocation method however is not straightforward, as it requires information on all possible sub-coalitions of the grand coalition. Because every sub-coalition is represented by a Pareto frontier and not by a single solution, the complexity of the problem increases significantly. Second, there is the multi-objective character of the problem. For every partner a cost efficient solution should be obtained, while time window violations should be minimized. A multi-directional variable neighbourhood search, that solves the problem without ranking or weighing the objectives in advance, is developed by the authors. The obtained result is a Pareto-front of non-dominated solutions.

2 - A Framework for Rich Vehicle Routing and Scheduling Problems
Illa Weiss, Christoph Schwindt

In this talk we propose a new modeling approach for integrated vehicle routing and scheduling problems. The generic problem setting consists in scheduling a set of activities that have to be performed at different locations in a network served by a set of vehicles and further resources like personnel or handling facilities. The activities may correspond to pickups or deliveries of goods at customer locations or to ambulant medical care services. The temporal relationships among the activities are subject to time lags, defining a minimum time span between the starts of the activities. An unconditional time lag must be observed, independently of the activity sequence, whereas conditional time lags only refer to activities that are executed immediately one after the other on the same vehicle tour. Unconditional time lags arise from constraints like time windows or synchronization requirements, and the conditional time lags generally represent the travel times among locations visited in one tour.

We explain how various requirements arising in practical vehicle routing and scheduling problems can be modeled as a multi-modal resource-constrained scheduling problem subject to conditional and unconditional time lags, involving transfer, storage, and renewable resources. Moreover, we present a constraint-programming framework and report on computational results for small and medium-sized problem instances with up to 20 customers.

■ TB-84

Tuesday, 10:30-12:00 - Architecture AR403, Level 4

Stochastic Models in Healthcare 1

Stream: Stochastic Models in Healthcare
Invited session
Chair: *Adele Marshall*

1 - Optimization of Surgeries Queue - An Application at the National Institute for Trauma and Orthopedics
Edilson Arruda, Cecília Siqueira, Laura Bahiense

The National Institute for Trauma and Orthopedics (INTO) is a Brazilian reference center for high complexity Orthopedic surgeries and performs most of the high complexity surgeries in the state of Rio de Janeiro. Their services are divided into fourteen distinct specialties, each of which can be served in any of the 21 surgery rooms they have available for nine hours each business day, and employ any of the 255 beds made available for post surgery care. Due to high demand and long surgery recovery times, INTO typically features a long waiting list for surgeries and ever increasing waiting times. This paper strives to develop a complete model of the underlying queuing process, taking into account both the problem of finding suitable surgery schedules for each room and the problem of finding an available bed for each patient that is subject to surgery, with a view to optimize the overall performance of the system. We present an integer-programming model for operating room scheduling optimization, which also includes a premise that the number of operations performed for each specialty must exceed the input rate of patients for that same specialty. Such a premise allows one to tackle the underlying queuing problem, thus allowing the decision maker to control the long-term behavior of the queues, according to a prescribed performance criterion.

2 - The Synergy between System Dynamics and the Coxian Phase-type Distribution: An Application in Healthcare Modelling
Adele Marshall

Health systems of developed countries around the world are facing immense pressure due to an ageing population and an increase in the prevalence of chronic disease. This accentuates the need for sophisticated modelling techniques which allow us to replicate the healthcare system. Such techniques would enable us to develop a comprehensive plan of action to improve the stability of our healthcare system through better allocation of resources. This paper proposes the development of a healthcare modelling approach in which the system dynamics methodology is combined with the Coxian phase-type distribution. System dynamics is a simulation technique well suited to modelling changes in the age structure and size of a population and the interactions between risk factor prevalence, primary and secondary interventions, and the prevalence of chronic disease. However, a limitation of this approach is the use of population averages in representing skewed patient length of stays. The Coxian phase-type distribution is a technique which is much better suited to representing the underlying distribution of length of stay. This research develops the system dynamics Coxian phase-type (SDC-Ph) modelling framework to investigate the change in prevalence of coronary heart disease (CHD) in Northern Ireland and the implications this will have on CHD related hospital admissions and the associated costs of such admissions.

3 - Differentiated waiting time management in an emergency care center
Seongmoon Kim

To reflect the special situation in emergency care centers included in this study, patient flows are formulated using an open Jackson network with multiple patient classes. This paper is unique because of the integration of pooling and prioritizing patient classes with the open Jackson network. In particular, a hybrid priority model is presented in which a first-come-first-served discipline is applied in some processes and a priority discipline is applied in other processes in the open Jackson network, in order to minimize waiting times for patients with more urgent concerns. A case study based on actual data from an emergency care center demonstrates that the proposed model of pooling and prioritizing patient classes is effective in decreasing waiting times for higher-priority classes without substantially sacrificing those for lower-priority classes.

Tuesday, 12:30-14:00

■ TC-01

Tuesday, 12:30-14:00 - Barony Great Hall

Keynote Lecture: Stefan Nickel

Stream: Plenary, Keynote and Tutorial Sessions
Keynote session
Chair: *Anita Schöbel*

1 - Is Optimal Still Good Enough? - Modern Supply Chain Planning
Stefan Nickel

Supply Chain Planning — as an important subtask of SCM — is the process of allocating resources over a network of interrelated locations with the goal to satisfy customer requirements (service level, demand, . . .). It spans all movements and storage of raw materials, work-in-process inventory, and finished goods from the point-of-origin to the point-of-consumption. Operations Researchers support Supply Chain Planning by developing adequate mathematical optimization models and providing suitable solution procedures. In this talk we discuss what adequate could mean.

Especially global supply chains have to face a rich variety of potential risks. Major incidents commonly referred to as disruptions such as strikes, natural disasters or political changes are widely known, but solely discussed on a conceptual and empirical basis. Permanently evolving market conditions such as up-and-down movements in oil prices or volatile exchange rates challenge the efficient execution of supply chains. Therefore, we may ask several questions concerning "optimality" in Supply Chain Planning under causal and temporal uncertainty: What is an optimal solution? When is it optimal? For how long is it optimal? How should the design of a supply chain be changed when conditions and requirements ask for new structures?

In this talk, we discuss new approaches to Supply Chain Planning in order to give an optimal transformation from an initial solution over multiple periods to a desired one rather than just specifying an optimal snapshot solution. Related to this idea, we re-coin the concept of risk in the realm of Supply Chain Planning. Here the question is how to measure supply chain specific risks and how to incorporate them into mathematical models. Finally, we have a look at the impact of recent technological developments like the Internet of Things or Industry 4.0 on supply chains, and we show how Online Optimization can help to cope with real-time challenges in Supply Chain Planning.

■ TC-02

Tuesday, 12:30-14:00 - Barony Bicentenary Hall

EURO Doctoral Dissertation Award, part II

Stream: EURO Awards and Journals
Invited session
Chair: *Hartmut Stadtler*

1 - Dynamic Pricing and Learning
Arnoud den Boer

'Dynamic pricing' is an umbrella term for practices where the selling price of a product or service is not a fixed quantity, but can easily be adjusted over time and adapted to changing circumstances. Classical examples are found in the airline and hotel industry, where prices are controlled by opening or closing 'fare classes', but nowadays many more applications can be found, e.g. in restaurants, concert halls, theaters, and amusement parks.

The availability of digital sales data enables firms to continuously learn about consumer behavior, and optimize pricing decisions accordingly. This has inspired a stream of literature on dynamic-pricing problems where estimation and optimization takes place simultaneously. The decision maker then faces the task of not only optimizing profit, but also optimizing the 'learning process'. A key question in these type of problems is whether a myopic or learning-by-doing approach - always

choosing the optimal price w.r.t. current estimates - has a good performance, or whether the decision maker should actively experiment in order to improve his/her knowledge on consumer behavior. In this talk we will discuss these questions for simple dynamic-pricing problems, and point to counterintuitive results and challenging open problems.

2 - From Structures to Heuristics to Global Solvers
Timo Berthold

In the literature for mixed integer programming, primal heuristics are often considered as stand-alone procedures; in that context, heuristics are treated as an alternative to solving a problem to proven optimality. This conceals the fact that heuristics are a fundamental component of state-of-the-art global solvers for mixed integer linear programming (MIP) and mixed integer nonlinear programming (MINLP). We focus on this latter aspect and study heuristics that are tightly integrated within an MINLP solver and analyze their impact on the overall solution process.

In this presentation, we introduce two novel large-neighborhood search heuristics, Undercover and RENS, that are designed to be employed as start heuristics inside a global solver. Undercover explores a mixed integer *linear* subproblem of a given MINLP. Therefore, an auxiliary vertex covering problem is solved to identify a smallest set of variables to fix such that each constraint is linearized. RENS uses a sub-MINLP to exploit the set of feasible roundings of a given solution of a relaxation.

We give theoretic motivations and discuss implementation details of both approaches. Computational results assess the ability of these heuristics to find feasible solutions and their impact on the overall performance of the MINLP solver SCIP. In this connection, we introduce a new performance measure, the primal integral, that depends on the quality of solutions as well as on the points in time when they are found.

■ TC-04

Tuesday, 12:30-14:00 - TIC Auditorium B, Level 2

Interface between OM and Marketing

Stream: Operations/Marketing Interface
Invited session
Chair: *Kathryn E. Stecke*

1 - Decision Bias of Strategic Customers in Rationing Risk: An Experimental Study
Xiaobo Zhao, Yanan Song

We consider a system with random number of heterogeneous strategic customers in a selling season. The customers have good knowledge of the stock quantity, the full price in the selling season (period 1), and the discount price at the end of the selling season (period 2). They can choose either to buy in period 1 or to wait for a discount in period 2 with rationing risk due to the possibility of stockout. Our purpose is to investigate the decision bias of such strategic customers. We conducted a laboratory experiment with subjects playing strategic customers. The results show that 1) the number of customers buying in period 1 is higher than the theoretical prediction; 2) both myopic buying and irrational waiting exist with the number of myopic buying customers increasing in experience; 3) each customer's cutoff value in the experiment is larger than the theoretical prediction; and 4) customers tend to overestimate the rationing risk. In addition, the extent of overestimate is decreasing in the stock quantity and increasing in the experience. We build upon the newsvendor model to discuss implications for seller's decisions. Based on the experimental observations, we suggest that when the newsvendor creates rationing risk, he can receive more profit due to the decision bias of strategic customers.

2 - Modeling Wholesale Electricity Prices: Merits of Fundamental Data and Day-Ahead Forecasts for Intermittent Power Production
Reinhard Madlener, Teppei Katatani

In this paper we develop a fundamental electricity pricing model with forward-looking weather information to investigate the impact of intermittent energy sources such as wind and solar photovoltaics (PV). Most electricity pricing models have used standard time series models that directly explain the movements of the electricity price, while the

inclusion of forward-looking information for electricity pricing is still scarce (Fuess, Mahringer and Prokopczuk, 2013). In our approach, we employ a mean-reverting Ohrnstein-Uhlenbeck process to model the stochastic behavior of conventional (restricted to nuclear and coal) and intermittent renewable energy (restricted to wind and PV) power generation capacity, electricity demand, and marginal fuel cost (restricted to natural gas). The competing models are calibrated with EEX spot price and day-ahead wind and solar power generation projection data of the TSO for Germany for the year 2011. The performance of the alternative model specifications is assessed by comparing their forecasting abilities in 2012 and Q1/2013 in terms of the mean root squares error and the mean average error. We find that the fundamental data model outperforms the time series model, and that the explicit consideration of day-ahead intermittent renewable power production data indeed helps to improve electricity price simulation.

3 - Pricing storages in control power markets
Philipp Hanemann, Thomas Bruckner

With growing shares of renewable energies, thermal power plant operators face increasing competition in electricity markets. This might affect the security of supply. On the one hand these plants are not on-line connected to the power grid which hence decreases the ability to provide spinning reserve. On the other hand energy resources as wind and photovoltaic are intermittent and therefore cannot provide spinning reserve with certainty. Remedy could be given by flexible storage plants. Battery storage plants for example can be synchronized to the grid without any minimal power requirement. Whereas the pricing of thermal power plants on the control power market is well understood, the economics of storage plants aren't. A main challenge constitutes the adequate inclusion of control power retrieval. This happens to be uncertain, depending on the position within the merit-order for energy bids. Furthermore a retrieval of control power does alter the state of charge of the storage and therefore restricts the ability to act on the spot market as well as on the control power market. The following work provides a stochastic dynamic optimization approach to calculate a lower bound on the capacity bid including the previously mentioned uncertainties into the optimal unit commitment.

4 - Optimization models for pricing in a waste management company
Carmen Galé, Herminia I. Calvete, Martine Labbé

This research addresses a recycle problem which arises in farming. A waste product must be gathered at some farms, stored and treated if needed, and released as organic fertilizer at some other farmlands at the appropriate moment. The product generator farms can also decide to handle the product themselves. Based on historical data, there is an estimation of the annual supply and demand of the product. The goal of this study is to deal with the problem faced by the recycle management company. The manager aims to determine the optimal prices to be set for coping with the product while maximizes the amount of product dealt with. There are constraints on the budget, as well as supply and demand constraints. In this work we analyze different optimization models which take into account the relationship between the company and the producers and users of the product.

■ TC-05
Tuesday, 12:30-14:00 - TIC Auditorium C, Level 2

Training Planning and Workforce Scheduling

Stream: OR Applications in Industry
Invited session
Chair: *Geir Hasle*
Chair: *Felix Brandt*

1 - Improving Operational Workforce Scheduling in a Warehouse Using Time Series Forecasting
Teun van Gils, Katrien Ramaekers, Kris Braekers, An Caris

In order to differentiate from competitors in terms of customer service, warehouses accept late orders from customers, while providing delivery in a quick and timely way. This leads to a reduced time to pick an order. In this study, the order picking process in a warehouse is discussed. In order to reduce the order picker travel time per order, the warehouse can be divided into different order picking zones.

Furthermore an improved workforce planning can contribute to an effective and efficient order picking process. Most order picking publications treat demand as known in advance. As warehouses accept late orders the assumption of a constant given demand is reconsidered in this study. The objective of this study is to present time series forecasting models which perform well in a warehouse context. Time series models are used to forecast daily number of order lines from a large international warehouse. The forecast of order lines, along with order picker's productivity, could be used by decision makers to determine the daily required number of order pickers, as well as the allocation of order pickers across warehouse zones. Time series are applied on aggregated level, as well as on disaggregated zone level. Both bottom-up, and top-down approach are evaluated in order to find the best performing method of forecasting in terms of RMSE, MAPE and MASE.

2 - Training Planning for a Globally Dispersed Workforce I
Felix Brandt, Stefan Nickel, Brita Rohrbeck, Mirko Wichmann

In this work we consider a large set of company locations and employees, who have to attend a one-time training. The problem is to determine an optimal subset of training locations from the given company locations and to assign each employee to one of the training locations. We show that the training-site-location problem can be formulated as a variant of the warehouse location problem. Furthermore, we consider restrictions like capacities, languages spoken, and cultural and legal issues. The objective is to find a cost-optimal plan with respect to setup, travel, and opportunity costs.

In our talk, we present the problem description and an integer programming formulation of the problem. We give an overview of the results obtained from a real world problem instance of one of our industrial partners. Our results show that there are significant savings achievable — both in planning effort and cost reduction.

3 - Training Planning for a Globally Dispersed Workforce II
Brita Rohrbeck, Felix Brandt, Marc Janschekowitz, Stefan Nickel, Frauke Tabert

The locations for a large-scale training of employees are often set by the company or can be determined cost-optimally in a first step like presented in the previous talk "Training Planning for a Globally Dispersed Workforce I'. In this talk we hence consider the setup of training events as well as the assignment of employees and trainers to the trainings if a set of locations is already given.

The training events are characterised by a specific time, room and language. In addition to the specifications made for the location decision, more detailed information can be regarded in this step. We consider restrictions like the number of releasable staff of company units in different periods, deadlines or preferences of the employees and trainers.

The solution of the location assignment problem is predefined or determined cost-optimal. Hence, the idea is to create a specific assignment of trainers and employees to trainings that minimises violations of the location decision properties.

Especially in large-scale projects, minor and major events can occur that were not expected or predictable whilst planning. Thus, we will complement our talk with an approach to adapt the initial schedule to these events with as little effort as possible.

For both approaches we will give the full problem description and an integer programming formulation of the problem as well as results from our real world instance.

■ TC-06
Tuesday, 12:30-14:00 - TIC Lecture Theatre, Level 1

POM I

Stream: Production and Operations Management
Invited session
Chair: *Anders Segerstedt*

1 - Product Greening and Competition under Environmental Regulations
Debabrata Ghosh

In this paper we explore the effect of environmental regulations and costs of greening on firms. We study two set ups namely, a single firm and a duopoly and derive strategic decisions of firms under each set up. We also analyze their impact on consumers. It is found that environmental regulation does serve the required purpose of forcing firms to provide higher greening levels. However it has a limited effect. A single firm for example, does provide higher greening levels but it is less than what is socially desirable. Further, greening costs do restrict firms from going green. As observed in practice, we verify that under competition, the firm with lower cost of greening has a better advantage in providing higher greening levels under government taxation. Additionally, under higher government penalty, a firm with a lower greening cost will offer higher product greening level than its competitor, in turn benefitting significantly in a green conscious consumer market. The results have interesting implications for policy makers as well. Through this problem we address the burgeoning challenges that firms face in the presence of competition and environmental regulations. This research lays the platform for future work in the area of 'green' product design, pricing and study of impact of environmental regulations on firms.

2 - Economic Order Quantities in production: From Harris to Economic Lot Scheduling Problems
Anders Segerstedt

A short historical overview from Harris and his Economic Order Quantity (EOQ) formula to the Economic Lot Scheduling Problem (ELSP) is presented. The aim is to describe the development of the ELSP field from the EOQ formula to the advanced methods of today in a manner that suits master and graduate students. The presentation/article shows the complexities, difficulties and possibilities of scheduling and producing several different items in a single production facility with constrained capacity. A heuristic solution method is used to illustrate different solution approaches. The solution method creates a detailed schedule and estimates the correct set-up and inventory holding cost even if the facility works close to its capacity. (The main idea in the solution method has also been successful applied to the JRP- and OWNR-problems.) How order quantities influence lead-time and production rates will also be briefly discussed.

References: Holmbom M., Segerstedt A. (2014). Economic Order Quantities in Production: From Harris to Economic Lot Scheduling Problems. International Journal of Production Economics, 155, s. 82—90. Martin Holmbom M., Pettersen J.-A., Lu W., Segerstedt A., Zhang Q. (2015). Order quantities in a production line, and its influences on production output and lead-time. Working Paper, Ind. Logistics, Luleå University of Technology.

3 - Impact of Discrete-Event-Simulation on Lean or Swift-Even-Flow processes in sorting facilities
Karthik Nagaraj Iyer, Wolfgang Garn, James Aitken

Lean and Swift-Even-Flow (SEF) operations are compared in the context of sorting facilities. Lean approaches tend to attack parts of their processes for improvement and waste reduction, sometimes overlooking the impact this will have on their overall pipeline. A SEF approach on the other hand is driven by a desire to reduce variations by enabling the practitioner to visualise himself as the material that flows through the system thus unearthing all the problems that occur in the process as a whole. This study integrates Discrete Event Simulations (DES) into the lean and SEF framework. A real world case study with high levels of variations is used to gain insights and to derive relevant simulation models. The models were used to find the optimal configuration of machines and labour such that the operational costs are minimised. It was found that DES and SEF have a common basis. Lean processes as well as SEF processes both converge to similar solutions. However, SEF arrives faster at a near optimum solution. DES is a valuable tool to model, support and implement the lean and SEF approach. The SEF approach is superior to lean processes in the initial phases of a business process optimisation. The primary novelty of this study is the usage of DES to compare the lean and SEF approach. This study presents a systematic approach of how DES and optimisation can be applied to lean and SEF operations.

4 - Balancing U-shaped un-paced mixed-model lines coupling a genetic algorithm and a discrete event simulator
Lorenzo Tiacci

To evaluate performances of U-shaped un-paced mixed model assembly line may be complicated. This complication is a result of blockage and starvation caused by the arrival of different models to the line, having different assembly time requirements at each side of a station. Considering the throughput as the main operational design objective, the effects of these phenomena on line throughput are very difficult to evaluate. Unfortunately, its evaluation is fundamental in almost all procedures and algorithms developed to solve U-MALBP (U-shaped Mixed-model Assembly Line Balancing Problem), since the estimation of objective functions that includes performance indicators is required. Traditionally, indirect measures of throughput (such as workload smoothness) are utilized, because they are easy to calculate. Unfortunately their correlation with the throughput is often poor, especially when the complexity of the problem increases. Algorithms are thus substantially driven towards wrong objectives. We show how a decisive step forward can be done in this filed by coupling the most recent advances of simulation techniques with a genetic algorithm approach. In particular a parametric simulator, developed under the event/object oriented paradigm, has been embedded in a genetic algorithm for the evaluation of the objective function, that contains the simulated throughput.

■ TC-07
Tuesday, 12:30-14:00 - TIC Conference Room 1, Level 3

OR in Water Management and Natural Resources 1

Stream: OR in Water Management and Natural Resources
Invited session
Chair: *Denys Yemshanov*
Chair: *Gerhard-Wilhelm Weber*

1 - A Bilateral River Bargaining Problem with Negative Externalities
Shivshanker Singh Patel, Parthasarathy Ramachandran

The river sharing problem between two agents along a river is considered for analysis. The agents contribute water to constitute a river and this contribution is based on the hydrological characteristics of their territories. Besides, each agent also has a stated claim to river water. In this regard predominantly two principles namely the Absolute Territorial Sovereignty (ATS) and the Absolute Territorial Integrity (ATI) have motivated the International Water Laws or treaties for trans-boundary river sharing. These principles are not considered as justifiable and equatable by the involved agents. In accordance to that the issue of negative externalities imposed by the upstream agent on the downstream agents in the form of pollution and flooding need to be addressed. This negative externalities impose cost on the downstream agent to mitigate pollution and loss due to flood. Their should be negotiated treaties, need to accommodate these issues in arriving at just and equitable sharing agreements. The analysis of a river sharing problem between two agents with negative externalities is studied with the view point of market based mechanism of bargaining. The utility form incorporates negative externalities in order to account for the agent's behavior. With the application of a bargaining formulation the individually rational bargaining strategies are characterized for the two agents. The results show agreement and disagreement points for bilateral trading.

2 - Towards a Generic Modeling Language for Water-Supply Systems
David Raz, Ariel Daliot

We look at modeling Water Supply Systems (WSS) systems for the purpose of optimizing energy costs. Energy costs are responsible for more than 90% of the operational costs of such systems and as such are the most important factor governing WSS operation. The major constraints for such an optimization are water volume constraints. This is in contrast to Water Distribution Systems (WDS) which may also be governed by water-pressure constraints. Existing modeling tools, such as the EPAnet software, are focused on WDS and as such they are very complex, concentrating on the physical properties of the system (pipes, valves etc.) rather than on water flow and electrical power consumption. We propose a simple generic modeling language for WSS. Although simple and generic, in our experience it suffices for describing WSS in enough details for energy cost optimization. The language has the major benefit that it easily translates into an LP model for optimizing energy costs. We describe the language and a graphic tool for building WSS models. We demonstrate how real-life constructs

translate easily into the modeling language and into an LP model. We discuss how the model may be efficiently solved. We show how the language can be easily expanded to incorporate other constraints such as pressure and other operational constraints. We express our hope that such a modeling language may be used to share network models by interested researchers and enrich the OR community.

3 - A Mixed-Integer Programming Model for Pump Operations in a Water Distribution System
Maristela Santos, Marcos Furlan, Edilaine Soler, Marcos Arenales

The problem focuses in on the minimization of the electrical energy costs necessary to manage water distribution network in a city in Brazil. In this system, water is abstracted from aquifers (wells) or from rivers using hydraulic pumps. The water from rivers is transferred to the treatment station and later, it is used to meet demand of users or is used to fill water reservoirs located in many stations in the city. On the other hand, the collected water from aquifers goes directly to the reservoirs and is used to meet demand from the districts and to fill the reservoirs. Population and the reservoirs can be supplied by gravitational force or using distribution pumps connected to storage systems (reservoirs). The water demand for each district is assumed to be known in each period in a finite horizon plan. For distributing and collecting water (in the rivers) using pumps, it is necessary to decide how many pumps are used in the operation. Since the cost of the electrical energy varies during the day, the operation of the pumps and water inventory in the reservoirs must be better planned. An integer linear optimization model is proposed for the problem considering a fixed cost for the starting of the pumps used for distribution and diversion of water. Instances based in a real case in the city are used to show that the proposed model offers consistent managerial support for its use in the real problem.

4 - Optimal Allocation of Invasive Species Surveillance with the Maximum Expected Coverage Concept
Denys Yemshanov, Robert Haight, Frank Koch, Bo Lu, Robert Venette

Decision makers tasked with planning the surveillance of invasive species often have to rely on uncertain knowledge about the capacity of an invader to spread to uninvaded areas, and face the dilemma of scarce resources available to conduct surveys but the aspiration to cover all possible entry pathways of invasion. We present a pest survey model based on the Maximum Expected Coverage Problem (MECP) that maximizes the expected number of source locations that are covered by the survey system, where an infested source location is considered covered if at least one of its transmission pathways connects to a surveyed uninvaded location. For each source location, MECP calculates the likelihood that there are one or more pest transmissions to surveyed destination sites. The model is formulated as a mixed-integer linear programming problem. We demonstrate the MECP approach by analyzing pathways of the human-mediated spread of the emerald ash borer (Agrilus planipennis Fairmaire), a major pest of ash trees in North America, by visitors to campgrounds in Canada and USA. The survey model was based on a pest spread network that involved campers traveling to campgrounds in three Canadian provinces (Ontario, Quebec and Manitoba) and three U.S. states (Michigan, Minnesota and Wisconsin). We compare the MECP model with a survey model based on a common ecological propagule pressure concept and further explore the trade-offs between the survey planning objectives and the survey budget.

■ TC-08
Tuesday, 12:30-14:00 - TIC Conference Room 2, Level 3

MAI: Making a deeper impact through design thinking.

Stream: Making An Impact 2 (MAI 2)
Invited session
Chair: *Geoff Royston*

1 - Making a deeper impact through design thinking.
Geoff Royston

Any OR/MS practitioner knows that clients often want support not only with decision analysis but also with the design of systems or processes. This workshop will introduce design concepts and provide examples of "design thinking' in operational research, explore with participants the extent to which their own practice entails this type of approach and consider how strengthening this could enhance their work and deepen its impact. Whether you are an experienced practitioner with your own reflections to share on the importance of design concepts and skills in "real world' operational research, or someone at an earlier stage of their career who wants to discover how thinking more like a designer can boost your work performance and professional profile, this workshop has been designed for you!

■ TC-09
Tuesday, 12:30-14:00 - TIC Conference Room 3, Level 3

Vendor Session II: Springer and LocalSolver

Stream: Vendor Sessions
Sponsored session
Chair: *Frédéric Gardi*

1 - EURO Advanced Tutorials in Operational Research — A Look Behind the Curtains of a Brand New Textbook Initiative
Christian Rauscher, M. Grazia Speranza

This sessions reflects recent developments in OR teaching at an advanced level, such as for PhD students and Post-docs. It provides a sneak preview of the first volume of "EURO Advanced Tutorials in Operational Research', edited by M. Grazia Speranza and J.F. Oliveira: R. Mansini/W. Ogryczak/M.G. Speranza, Linear Mixed Integer Programming for Portfolio Optimization, and sheds light on the motivation for the development of these new "shorter teaching modules'. A good occasion for lecturers to discover this valuable new teaching resource, and for prospective authors to get in touch with the series editors or the publisher.

■ TC-12
Tuesday, 12:30-14:00 - TIC Conference Room 4&5, Level 3

Energy Efficiency and Industry

Stream: Long Term Planning in Energy, Environment and Climate
Invited session
Chair: *Gilles Guerassimoff*

1 - Decision Making Tool for Improving Energy Efficiency in the Industry Sector
Gilles Guerassimoff

This presentation expose the methodology developed for the modeling of the industry sector for prospective studies. These models give a sample of results that aim at helping the stakeholders in the long term industry planning for the development of the low-carbon technology deployment. We have developed several models using the linear programming model generator TIMES. Due to the industry sector diversity of activities and depending on the level of the energy use in the processes, the industry can be divided in two big families: the energy intensive industries and the non-energy intensive ones. A big challenge is to provide a methodology to be able to represent their evolution in a mid-term to a long-term period. The Centre for Applied Mathematics had developed for a long time several models for different activities. It is involved in this research theme with EDF (French Electricity Company) to establish a frame for industry modeling with the most pertinent representation to improve industry energy efficiency by promoting low-carbon technologies. The results obtained for both energy intensive and non-energy intensive industry permit to assess the potential of integration of low carbon technologies and their effect on a mean to long term period. Some examples are presented to enlighten the potential of this kind of modeling.

2 - What about electricity as an alternative to coal to reduce carbon emissions from steel industry? The answers from TIMES model.
Alain Hita

Steel industry contributes for around 30 % of carbon emissions from world industry. It is the largest emitting sector in industry. To address this problem, all the solutions must be taken into account, even the breakthrough technologies. Using electricity instead of coal can reduce direct emissions of the process. A low-carbon electricity (renewable, nuclear) then guarantees the low CO2 overall balance of the process. Can an iron ore be reduced by electricity? The answer was provided by the European project ULCOS (Ultra Low CO2 steelmaking), which was completed in 2010. It has been proved experimentally that it is possible to do this by direct electrolysis of the iron ore. The breakthrough technology is in the demonstration phase, studied in IERO European project. To be adopted by the industry, the electrical process must be "low carbon" but also "competitive." We use a prospective energy model to assess the response of industry in different macroeconomic scenarios. It calculates the best economical choices for technology adoption. It shows the consequences in terms of reducing carbon emissions.The modeling tool is TIMES model (family of best known MARKAL model). We will present our results for steel industry, in Europe, at the prospective year of 2050. Electrical techniques are competitive technologies in terms of energy performance. The macroeconomic evolution of energy prices and the carbon price are the main drivers for the technical choices of steel industry.

3 - Production development in the pulp and paper industry of Germany
Klaus Biß

Improve energy efficiency in every sector of the energy system states one of the three main pillars for the German „Energiewende'. In order to investigate this pillar, a wide range of possible technologies is considered in bottom up energy models. Besides detailed description of technologies, one essential input in such models is the energy service. The demand of those is the driving force for the model. Demands are for example the development of quantity of goods, transport distances, or heated living space. Since energy demand by energy services determine the absolute saving potential by energy efficiency, it is important to describe the energy services in more detail. In case of the industry sector this is achieved by forecasting the production of each branch. Those forecasts should be transparent and easy to adjust to different scenarios. For this reason, the Dow Jones Concept (DJC) was introduced by investigating the production of the pulp and paper industry. The DJC is based on the idea that the development of a time series is an overlap of different trends with different duration. This allows to add or to adjust a single trend easily. As a consequence information of macro economic models or population growth could be considered in a transparent way. Furthermore, the observation of sub-commodities allows a differentiated modification of those. In case for newsprint paper this opportunity was used to investigate the trend shift in more detail.

4 - industrial Energy Efficiency strategy - Danone case
Olivier Barrault

Certinergy Group is a 350 employees Company and more than 100M EUR turnover. We advice since more than 40 years our industrial customers worldwide in building and apply their Energy Efficiency strategy. The aim of this presentation is to explain our methodology and results through the exemple of Danone Group since the last 15 years. As matter of fact, this 3 stages' rocket includes first the improvement of existing means on site, including audit approach, measurement and monitoring, training from Directors down to operators. The second stage carries out proper Engineering on Utilities and Process as part of a real energy master plan sticking to the industrial one. And the last stage of this rocket is to imagine the tomorrow's plant, new process design, products or packaging, till collaborative innovation and even breakthrough technologies (green CIP example).

■ TC-15

Tuesday, 12:30-14:00 - TIC Conference Room 6&7, Level 3

Game-theoretic Analysis in SCM

Stream: Supply Chain Management
Invited session
Chair: *Susan Li*

1 - Game-based Modelling for the Optimal Management of Decentralized Supply Chains under Competitiveness
Kefah Hjaila, José M. Laínez-Aguirre, Luis Puigjaner, Antonio Espuña

Current SCM tactical models support decisions based on the global objective of one centralized organization, disregarding the arising complexity when different organizations are involved, each one seeking to optimize its own objectives regardless the other participant's uncertain reactions. This work provides a decision support tool for decentralized SCs coordination by determining the best conditions to establish win-win coordination contracts among the different partners. Under the leading role of the SC of interest "leader", the interactions with the different followers are modeled as a single-leader—single-follower non-cooperative non-zero-sum Stackelberg game. The reaction function is identified (price vs. quantity) and, assuming a complete information dynamic game, the leader designs its moves (prices) according to the follower expected offers (amounts), which are calculated according to its expected benefits, so the Stackelberg-payoff matrix can be built, including the optimal profits of the leader SC every scenario, and the corresponding expected profits of the follower SC. Results show the importance of considering this wider view of the followers' options. Acknowledgements: Financial support from the Spanish Ministry of Economy and Competitiveness and the European Regional Development Fund, both funding the Project SIGERA (DPI2012-37154-C02-01),and from the Generalitat de Catalunya (AGAUR FI program and grant 2014-SGR-1092-CEPEiMA), is fully appreciated.

2 - Impact of Power Structure on Supply Chain Performance and Consumer Surplus
Jian-Cai Wang

In this study, we consider a game-theory-based framework to model power in a supply chain with price-dependent stochastic demand and investigate how power structure (dominant retailer, dominant manufacturer, or balanced power) affects supply chain efficiency, members' profit and consumers. We analyze all problems in this framework and characterize their equilibrium outcomes. By comparison, we demonstrate that, a firm always benefits from its power, a balanced power structure is conducive to the whole supply chain, and power structure acts on consumers in much the same way that they do on channel efficiency. In other words, consumers often cannot profit from a power retailer. We also numerically investigate the effect of demand model (demand curve and shock), point out the resultant differences and discuss the underlying reasons.

3 - Fairness in Profit Allocation in a Coordinated Project Supply Chain
Niladri Palit, Andrew Brint, Alok Choudhary

The coordination of supply chains using different modelling techniques has received considerable attention in the literature. However, limited research has been carried out considering the issue of the fair allocation of derived profit and risk. Usually, the allocation is arbitrarily left with bargaining power of the members. Recently, some research has empirically shown problems in coordinated supply chains in the absence of proper fair allocation mechanisms. Very few models of fairness have been proposed in the context of supply chain coordination. However, these models did not consider the effects of loss of efficiency due to its emphasis on fairness. Therefore, there is a need to propose a model of fairness for the equitable allocation of risks and benefits while achieving the supply chain coordination. This research proposes a model a model to maximize the utilities of the members of a buyer-seller supply chain with consideration of fairness in a project environment. Nash's bargaining model is used to maximize the products of the two utilities. The proposed research extends the existing models by including constraints such as: constraints of bargaining power and minimizing the loss of efficiency due to fairness.

4 - Interactive Game Models in a Supply Chain Inventory System
Susan Li

This paper deals with a situation where the buyer has a monopolistic position, and examines the issues and advantages of cooperation in a buyer-seller supply chain system. Game theory concepts form the foundation for our analysis of these issues. First, the relationship between the buyer and the seller is modeled as a non-cooperative game. In this structure, the Stackelberg equilibrium concept is applied. Then the mutual incentives and motivations for system cooperation are discussed. Interactive game theory is utilized to determine optimal system order quantity-price schemes. Among several alternative methods,

the combination of an equal profit sharing rule and quantity discount is shown as best for achieving system cooperation. The similarity and differences between our model and those in the literature are discussed.

■ TC-16

Tuesday, 12:30-14:00 - TIC Conference Room 8, Level 3

Lot Sizing and Scheduling Problems

Stream: Lot Sizing, Lot Scheduling and Related Problems
Invited session
Chair: *Bernardo Almada-Lobo*
Chair: *Christian Almeder*

1 - Accounting for form capacity, cleaning and set-up times in short-term lot scheduling of cheese production

Bryndís Stefánsdóttir, Martin Grunow

Despite an increasing interest in scheduling in the dairy industry, the main focus in literature is on yoghurt production whereas the specific challenges encountered in cheese production have not been addressed. In this study we explore short-term lot scheduling of soft and blue cheese production on a single production line. The main production processes are analyzed, which are mixing, clotting, cutting and stirring, filling into forms, resting and brining. We propose a mixed integer linear programming (MILP) model using a mixed continuous and discrete time representation, with a planning horizon of one week. Due to a zero wait storage policy between production stages, the problem can be reduced to a single stage. The aim is to improve the production schedule such that production on weekends is minimized. We address several important aspects for lot scheduling in this industry such as sequence dependent setup times, fixed daily and flexible intermediate cleanings, due date restrictions and precedence relations between products. Also form usage must be tracked as forms are blocked for several hours after filling and represent a key bottleneck. The developed approach is implemented for a medium-sized dairy company in Germany, demonstrating the practical applicability and computational efficiency of the approach.

2 - Is the vertical integration of production planning levels always beneficial?

Christian Almeder, Bernardo Almada-Lobo, Tom Vogel

We consider two examples of vertical integration in production planning. First, we present a model which combines the planning levels of master production schedule (MPS), material requirements planning (MRP) and shop floor scheduling. We use a classical multi-level capacitated lot-sizing problem (MLCLSP) and include explicitly the scheduling aspect. Second, we suggest and a model which combines the aggregate production planning (APP) with the master production schedule (MPS). In the first approach we show through small examples and numerical experiments that without integrating those planning levels, infeasible production plans which cannot be executed on the shop floor are very likely. In the latter approach the integration seems beneficial when planning is performed just once. But in the case of a stochastic environment and replanning frequently utilizing a rolling planning horizon approach the integrated approach is no longer superior to a classical hierarchical planning process.

3 - Lot-sizing and scheduling of parallel continuous processes under demand uncertainty

Georgios M. Kopanos

This work presents an extension of the model of Kopanos et al. (2011) to deal with uncertain demands for products. That model is a mixed integer programming formulation for the production planning and scheduling of parallel (single-stage) continuous processes in the presence of sequence-dependent setup times and costs for product families, and sequence-independent setups for products that belong to the same family. The presented model is a combination of a discrete-time planning (big-bucket) grid with a continuous-time treatment of the scheduling decisions within each period and across adjacent periods. More specifically, at the production planning level, it handles product orders at intermediate due dates and accounts for holding and backlog costs. At the scheduling level, it accounts for equipment unit constraints,

setup times and costs, maintenance activities, and idle production periods. The proposed model was motivated from and implemented to a real-world production facility. It can effectively address industrial-scale planning-scheduling problems. Here, an extended rolling horizon version of the previous model is also presented and applied to some problem instances to highlight the need and the significance of the proposed approach in dynamic production environments. A discussion on key points of rolling horizon approaches is finally provided.

Reference: Kopanos et al. (2011) Industrial and Engineering Chemistry Research, 50 (3), 1369-1378.

4 - Industrial Insights into lotsizing and scheduling

Bernardo Almada-Lobo, Luis Guimarães, Pedro Amorim, Gonçalo Figueira

Lotsizing and scheduling by mixed integer programming has been a hot research topic in the last 20 years. Researchers have been trying to develop stronger formulations, as well as to incorporate real-world requirements from different applications. In this talk we will categorize some of these requirements and show how models have been adapted and extended. Motivation comes from different industries, especially from process and fast moving consumer goods industries.

■ TC-17

Tuesday, 12:30-14:00 - TIC Conference Room A, Level 9

IBM Research Applications II

Stream: IBM Research Applications
Invited session
Chair: *Odellia Boni*
Chair: *Marco Laumanns*
Chair: *Martin Mevissen*

1 - Strategic Project Planning: Optimal Contracting, Resource Allocation and Risk Mitigation

Bruno Flach, Carlos Raoni Mendes, Marcus Poggi

We study the problem of determining optimal activity execution modes and risk mitigation plans within a project's execution context subject to multiple sources of uncertainty. The uncertain environment is modeled as an adversary who selects a worst-case (highest impact) combination of risks given the decision maker's actions and we devise a strategy based on robust optimization to account for that. We present a reformulation scheme coupled with a cut-generation algorithm to solve the proposed problem and illustrate the approach by a series of computational experiments.

2 - Making the right decision: a toolkit for optimization under uncertainty

Rudi Verago, Chungmok Lee, Marco Laumanns, Susara van den Heever, Martin Mevissen, Nicole Taheri, Bissan Ghaddar

Taking the right decisions for a business user can be difficult when there are only a few variables and possible outcomes. Making complex decisions is even harder when the data includes uncertainty arising from, for example, approximations and aggregations, error in instrumentation, and predictions of volatile supply and demand patterns. Moreover the optimization under uncertainty involves many challenges such as large numbers of scenarios, complex mathematical models for stochastic and robust optimization, and lack of user adoption. We present a decision support system aimed at addressing these challenges, called Uncertainty Toolkit. The prototype is a collection of user friendly tools developed, also, as a generic plugin of IBM Decision Optimization Center. This toolkit solicits information on the uncertain data, automatically generates models which incorporate the uncertainty, and it includes visual analytics for trade-off analysis, a scenario generator and decomposition techniques.

3 - A Distribution Shaping Approach for Stochastic Project Planning

Marco Laumanns, Steven Prestwich, Ban Kawas, Bruno Flach

A new approach to handle endogenous uncertainty in stochastic programs will be presented, which allows an efficient polyhedral characterization of decision-dependent probability measures and thus a reformulation of the original nonlinear stochastic MINLP as a stochastic MIP. The effectiveness of the approach will be demonstrated for stochastic PERT networks where the probability of activity delays can be reduced by investing additional resources in order to minimize expected project duration.

■ TC-18

Tuesday, 12:30-14:00 - TIC Conference Room B, Level 9

Energy Market Modeling 4: Financial Modeling of Energy Markets

Stream: Energy Market/System Modeling
Invited session
Chair: *Gerhard-Wilhelm Weber*
Chair: *Ezgi Avci-Surucu*

1 - Energy: A Panacea to Sustainable Economic Growth in Nigeria

Kingsley Imoh, Akpanim Ntekin Ekpe, Martina Paulinus Effiong, Martina Paulinus Effiong

Energy is a major factor for sustainable economic growth. It is the engine room for socio-economic growth. In Nigeria, electricity generation cannot equate with the high rate of demand for it as a result of population rate. Hence, the problem of insufficent electricity supply since the alternative sources is almost out of sight.The access to modern energy becomes an impossible task. This paper brings into limelight the direction of the functional relationship that exist between the quantum of electricty generation and sustainable growth using Granger Causality test and also a multiple regression analysis to explore the impact of energy usage and economic growth. There was a witnessed a bidirectional relationship between energy usage and gross domestic product which contributes to economic growth in the country. It was suggested that the government should increase investment in the energy sector.

2 - An Integrated Lean Energy Framework and Its Application in Footwear Industry

Ali Kaylan, Kadir Yildiz, Tülin Aktin

This study aims to develop an integrated methodology for factory level energy demand management. The proposed approach is implemented in a footwear company. What is unique in this study is that the methodology combines lean manufacturing principles with energy economics analysis and optimization. As a first step, an initial assessment of the current energy consumption profile is realized identifying the major energy-consuming units. Accordingly, improvement opportunities are proposed to ultimately reduce energy consumption. These retrofitting opportunities are evaluated through lean methods. More specifically, energy value stream mapping is employed as a key instrument for the lean analysis. The promising opportunities are economically analyzed using energy price forecasting and Monte Carlo Simulation and then optimized according to their investment costs and potential savings with a simple model that is later solved with GAMS 23.5.1 software. Consequently, energy value stream maps are revised for the future status. The total energy consumption per product is compared before and after the application of the suggested improvements. The results showed that with short payback periods and small budgets, the energy use of the company could be optimized.

3 - A note on Electricity Market Monitoring Indexes: A case of an Emerging Market

Ezgi Avci-Surucu

Turkey's energy reforms are mainly based on energy security through diverse measures including electricity, gas, renewable energy and energy efficiency legislation; the establishment of an energy sector regulatory authority; energy price reform; the creation of a functional electricity market; restructuring of state-owned energy enterprises; and private sector participation through privatization and new investment. However, current regulations, namely, "Electricity Sector Reform and Privatization Strategy" and "Electricity Market and Supply Security Strategy", have been criticized for various aspects. The present paper analyzes the implementation of the aforementioned strategies in the framework of price and risk management, infrastructure, customer focused regulations and systematic market development; and argues on the deficiencies of current strategies which creates uncertainties for market participants. We conclude by policy suggestions and new market monitoring indexes to eliminate these deficiencies.

4 - Response surface optimization of an artificial neural network for predicting the CO2 emissions from electricity generation

Zeynep Ceylan, Seniye Ümit Oktay Fırat, Okan Özgönenel

The rapid development in economy and industry and growth in population have led to increased demand for electric energy. Electricity generation in Turkey highly depends on fossil fuels such as coal and natural gas which has resulted in increased amounts of carbon dioxide (CO_2) emissions. CO_2 is the primary greenhouse gas and the main cause of global warming. In this study, a three-layer Artificial Neural Network (ANN) optimized by Response Surface Methodology (RSM) was built to estimate resultant CO_2 emissions from electricity generation. The data used in this study were collected from the Ministry of Energy and Natural Resources (MENR) of Turkey and the Turkish Statistical Institute (TURKSTAT). The input parameters of the model were population, gross domestic product (GDP), imports, and exports data of Turkey between the years 1979 and 2013. A multi-layer feed-forward (MLFF) network using gradient descent with momentum (GDM) as learning algorithm with one hidden layer was applied for building a predictive model. The face-centered full Central Composite Design (CCD) was applied to find optimum values for the number of hidden neurons, training epoch, step size and momentum coefficient in the hidden layer, and training runs. Also, a quadratic equation was developed based on training results and applied to mean square error (MSE) of 50 artificial neural networks as the response. The best ANN model was used to predict CO_2 emissions related to electricity generation up to 2023.

■ TC-24

Tuesday, 12:30-14:00 - John Anderson JA3.25 Lecture Theatre

MAVT methods for MCDM

Stream: MCDM
Invited session
Chair: *Theodor Stewart*

1 - A Framework for Designing Alternatives

Alexis Tsoukiàs, Alberto Colorni

The talk presents the structure of a general framework within which decision analysts can construct alternative for some decision processes and a given decision maker. The framework borrows ideas from Valued Focussed Thinking, from other problem structuring approaches, as well as from more traditional tools such as decision trees and mathematical programming. It also considers both conceptual and algorithmic issues.

2 - Multicriteria Evaluation of Heating Choices for Residential Houses

Risto Lahdelma, Kaisa Kontu, Pekka Salminen

The city of Loviisa in South-Eastern Finland is planning a new sustainable residential area. The city wants to promote sustainable energy solutions in the area, considering various renewable energy forms for heating and applying wood constructions. The aim of this research was to evaluate which heating system would be best when different technical, economic, environmental and usability criteria are considered. The citizens were involved with a questionnaire to provide preference information for different criteria. MAVT-based SMAA-2 method (Stochastic Multicriteria Acceptability Analysis) was used to analyze the problem. The SMAA method was extended to handle a hierarchy of criteria and sub-criteria. The problem was analyzed in two phases first without the preference information from citizens and after this with the information. The results were quite similar in both analyses, indicating that the problem is quite robust with respect to preference information.

3 - Reflections on Structuring Needs for Value Function Models
Theodor Stewart

Value function methods have the advantage of being simple and transparent, but do in principle require strong assumptions. However, not all assumptions are equally critical. The facilitator needs to understand which are most critical, and to guide model construction accordingly. We shall reflect particularly on the building of partial values, different meanings and implications of independence properties, and the role and elicitation of weights.

■ TC-25

Tuesday, 12:30-14:00 - John Anderson JA3.14 Lecture Theatre

Environmental Sustainability in Supply Chain Networks

Stream: Environmental Sustainability in Supply Chains
Invited session
Chair: *Emel Aktas*

1 - Time-to-Sustainability as optimization strategy for supply chain network design
Matthias Kannegiesser, Hans-Otto Guenther, Niels Autenrieb

Sustainability with its multiple social, economic and environmental objectives has been approached so far with multi-objective optimization strategies. Decision makers needed to define weights discriminating one objective over the other and/or were confronted with single period trade-off results. In supply chain network design, however, decision makers need to know how to transform a supply chain network towards multiple sustainability goals over several periods of time. Companies increasingly set long-term targets for multiple sustainability goals, e.g. CO2 emission reductions, recycling rates, preservation of jobs or ensured profitability. Decision support models need to answer if, how and when these multiple sustainability goals can be all achieved. Since complex dynamics and interrelations between these goals exist in a supply chain network, simple static scenario planning is insufficient either. We propose the Time-to-Sustainability (TTS) optimization strategy as a new approach for long-term supply chain network design. TTS minimizes the time frame until predefined targets for multiple sustainability indicators are achieved steady state. This way, TTS delivers new insights on how supply networks transform towards a sustainability steady state and allows decision makers to validate the feasibility of long-term sustainability targets. Three variants of the TTS approach are presented and evaluated using data from the automotive industry.

2 - A Multicommodity and Multimodal Service Network Design Problem with Uncertain Travel TImes
Martin Hrusovsky, Emrah Demir, Wolfgang Burgholzer, Emel Arıkan, Werner Jammernegg, Tom Van Woensel

In a more and more competitive and global world, distances between supply chain actors are increasing which leads to growing freight transport volumes. In this environment, intermodal transport combining different transport modes (e.g. road, rail, inland waterway) allows to exploit their individual advantages offering flexibility and reducing environmental impacts of transport. Especially for long distances, the consolidation of transport flows leads to cost advantages in comparison to unimodal transport by road and the use of standard units (e.g. containers) facilitates the transhipment of goods in terminals. However, the use of multiple transport modes in one transport chain also brings the challenge of coordinating them and creating robust transport plans which consider their individual characteristics (e.g. fixed schedules, routes) and account for possible delays or disruptions of the transport service.

In order to represent the complexities mentioned above, we present a service network design approach with uncertain travel times which considers the capacity, costs, travel and service times, emissions and schedules of transport services and transhipment points. This approach allows generating robust transport plans according to different objectives (i.e. costs, time, emissions) by considering uncertainties in travel times with the help of sample average approximation. The model can be used for offline planning as well as online re-planning in case of disruptions.

3 - Location Decisions for Supply Chain Sustainability
Emel Aktas

Location decisions are critical for supply chains. There is an increasing pressure from customers, regulatory bodies and employees that environmental and social impacts of organisations are also considered together with economic aspects. The interdependence of ecological, social and economic systems is captured in the sustainability concept. In the context of location decisions and supply network design, sustainability imposes that any development and design decision in location planning must also consider social and environmental aspects. This research extends the existing facility location literature by integrating environmental and social sustainability concerns with the classical location decision problem. For that purpose, initially, environmental and social sustainability objectives for location decisions are identified and the associated measures are quantified. Then, a multi-objective optimisation model is built to support location decisions, deriving the Pareto solutions given a location decision problem. The novelty of this research is that it incorporates sustainability dimensions explicitly in the location decision: where to locate a recollection facility so that its negative impact on the environment (CO_2, water, ecosystem, resources) is minimised and its positive impact on the society (employment, education, welfare, health) is maximised in addition to the objective of minimising transportation and investment costs.

4 - Inventory control with stochastic lead times and yearly emission constraints
Johannes Fichtinger

Considering environmental emission constraints in inventory control has become an important stream of research. Emission constraints are often formulated as yearly targets for the business, either in absolute terms or relative savings to previous years. In this paper we analyse a multi-period inventory control problem with a yearly emission constraint in the global sourcing context under a deterministic demand but stochastic lead time scenario. We present the inventory policy, the optimal ocean carrier decision based on stochastic dominance and discuss the impact of emission targets on the optimal decision.

■ TC-26

Tuesday, 12:30-14:00 - John Anderson JA3.17 Lecture Theatre

Stochastic Models in Manufacturing and Logistics II

Stream: Stochastic Modeling
Invited session
Chair: *Raik Stolletz*
Chair: *Axel Franz*

1 - Throughput in tandem queue with multiple unreliable servers and finite buffer
Yang Woo Shin, Dug Hee Moon

The tandem queue also known as the serial line in which servers and buffers are linked along a single ow path one after another is widely used for modeling manufacturing system. In this talk, we present an approximation method for throughput in tandem queues with multiple unreliable servers at each node and a buffer of nite size between service stations. If the buffer of a stage is full when a service is completed at the previous node, the customer that completes its service must wait there until there is an available space in the next node. This type of blocking is called blocking after service (BAS) blocking. The service time, time to failure and time to repair of each server are assumed to be exponentially distributed. The throughput of the system is approximated by using the decomposition method that is to decompose the whole system into a set of coupled three-stage subsystems with two buer spaces. Each subsystem is modeled by the level dependent quasi-birth-and-death process and analyzed by the matrix analytic method.

2 - A stochastic model for two-stage lot sizing in a serial production system considering flow time aspects
Hubert Missbauer

Despite many efforts to reduce setup times, lot sizing continues to be an important planning task in manufacturing planning and control. In the past decades substantial progress has been made in the domain of dynamic lot sizing which normally aims at minimizing the sum of setup and inventory holding costs. However especially in discrete manufacturing, standard lot sizes (that can be adapted to demand fluctuations over time) can be a reasonable alternative. This provides the possibility to consider the impact of lot sizes on the relationship between flow time, WIP and output. Lot sizing models of this type are mostly based on queuing models and have been developed mainly for single-stage production (that can be a network of work centers). We develop an approximate analytical model for a two-stage serial production with identical products, assuming a single server per stage including queues at the servers and SKU inventories. Furthermore, we assume an echelon stock inventory control policy and derive an M/M/1 approximation for both stages. We show that mainly by altering the inventory control parameters the flow time effects of lot sizes (resulting from the queuing characteristics of the servers) influence the entire system. We also test to what extent structural properties of single-stage models extend to this two-stage setting.

3 - Optimal FCFS allocation rules for Assemble-To-Order systems
Ton de Kok

Due to increasing diversity of customer requirements and the adoption by the customer of the internet as the main channel for buying durable goods, more and more companies migrate from a make-to-stock supply chain to an assemble-to-order supply chain. Controlling an assemble-to-order supply chain based on customer demand forecasts and customer orders as they develop over time poses major planning and control challenges, which current APS systems are unable to support. We consider periodic review ATO inventory systems consisting of end-products assembled on customer order from components. Components are ordered from outside suppliers with constant lead times. In case of customer backlogs due to insufficient component availability, we must allocate component availability over time to backlogged customer demands. We present recent results on optimal FCFS allocation policies, so-called multi-matching policies, which apply to a great variety of component ordering policies and no particular assumptions on the demand process. The main result of our analysis is that under the FCFS allocation assumption, the optimal allocation policy under stochastic demand follows from solving a linear program each period. We discuss possible extensions of our findings for N-echelon ATO systems under FCFS component allocation.

4 - Inventory management under randomly fluctuating prices
Caner Canyakmaz, Fikri Karaesmen, Suleyman Ozekici

We consider a single-item, multi-period inventory model where purchase and sales prices fluctuate randomly. This case is typical for retailers that trade products consisting of commodities whose prices constantly change and are determined at an outside market. We assume that a time-homogeneous and Markovian stochastic market price process represents purchase prices for the retailer and determines the sales prices through a markup rate. Customers who demand a random amount of the item arrive according to a doubly-stochastic Poisson process where stochastic arrival rates are determined by a rate function which takes the sales prices as input. Upon observing the inventory level and market price, the retailer decides on order quantity at each period to maximize the expected profits. In the case of exogenous markup, we show that a price-dependent base-stock policy is optimal for any nonnegative price process if backordering is allowed. We provide necessary and sufficient conditions on the price process to ensure concavity of the profit functions in lost-sale case. In the case where retailer also sets the markup rate, we give a sufficient condition to ensure the joint concavity which suggests that a base-stock list-markup policy is optimal. Lastly, in a numerical study, we analyze the effect of price variability on the optimal expected profits and base-stock levels for various price processes and observe that a more volatile price process leads to lower optimal expected profits.

■ **TC-27**
Tuesday, 12:30-14:00 - John Anderson JA3.27, Level 3

Parallel Machine and Flow Shop Scheduling

Stream: Scheduling, Sequencing, and Applications
Invited session
Chair: *Bartlomiej Przybylski*
Chair: *Malgorzata Sterna*

1 - Single Machine Two-Agent Scheduling Involving a Just-in-Time Criterion
Omri Dover, Dvir Shabtay, Moshe Kaspi

We study a set of single machine two-agent scheduling problems where the performance measure of the first agent, F1, is the weighted number of jobs completed exactly at the due date, i.e., completed in a just-in-time mode. The performance measures of the second agent, F2, is either the makespan, the total completion times or the weighted number of jobs completed exactly at the due date. For each combination of performance measures of the two agents, we study four different variations of the problem. We show that all four problem variations are strongly NP-hard for when the performance measure of the second agent is either the makespan or the total completion time, even if all of the first agent's weights are equal. We also study the special case of these problems where the job processing times of the second agent are all equal. For this special case we prove that three variations of this problem are ordinary NP-hard with respect to the instance size, while all four problem variations are polynomial solvable with respect to the number of jobs. For the problem where the performance measure of both agents is the weighted number of jobs completed at the due date, we show that one problem variation is solvable in polynomial time, while all other three variations are ordinary NP-hard.

2 - Off-Line and On-Line Late Work Minimization on Parallel Machines
Malgorzata Sterna, Xin Chen, Xin Han, Jacek Blazewicz

We investigated the scheduling problem on parallel identical machines with a common due date and the total late work criterion. Late work performance measure estimates the quality of a solution on the basis of the duration of late parts of jobs. This means that jobs arriving into the system, have to be assigned and scheduled on machines, preferably before the given due date, in order to minimize their late parts. In off-line case all jobs are known in advance, while in on-line case they appear in the system one by one. Late work criterion has not been analyzed in on-line environment yet. To study the on-line model, we had to determine the complexity of its off-line version. We proved the binary NP-hardness of the off-line case for two identical machines. We showed the transformation from the partition problem and proposed the pseudopolynomial time dynamic programming algorithm. Then, we proposed the online algorithm for an arbitrary number of machines, proving its competitive ratio representing the upper bound of the distance between the optimal offline solution and any online solution. Moreover, we showed the optimality of this approach for two machine case, i.e. the equality of its competitive ratio and the lower bound of a competitive ratio of any online algorithm.

■ **TC-29**
Tuesday, 12:30-14:00 - John Anderson JA4.12, Level 4

Emerging Applications of OR in Economics

Stream: Emerging Applications of OR in Economics
Invited session
Chair: *Dmitri Nizovtsev*

1 - Incorporating Sustainability into Replacement Decisions Concerning Corporate Infrastructure
Petra Hutner, Martin Dirr

Nowadays, managers are supposed to not only consider economic, but also environmental aspects of investment decisions in order to properly

integrate the concept of sustainability into corporate decision-making. However, there is a lack of research concerning the implementation of the environmental dimension into traditional managerial toolsets. Against this background, we propose a model that embeds environmental aspects into infrastructure replacement decisions. More precisely, we develop a multi-criteria decision-support model that extends the well-acknowledged replacement problem which determines the optimal point of time for replacing existing corporate infrastructure. In addition to the two traditional factors capital expenses and operating expenses, we incorporate the environmental performance of the investment alternatives over their lifetime including the production phase. One major challenge is the proper estimation of environmental impacts, which range from CO_2 emissions to other pollutants that negatively impact eco-system quality and human health. These parameters are quantified by implementing a cradle-to-grave approach using life-cycle assessment. To demonstrate the practical value of the presented approach, we apply our model to a generic case that optimizes the replacement of IT infrastructure.

2 - Applications of preferences, utility functions and multiobjective optimization methods in insurance companies.
Ulkar Ahmad-zada

This work illustrates the applications of decision making process in insurance companies from the first step of taking risk to the final analyses of the occurred losses in order to reach a better results in future estimation process. The paper shows the mechanism of preferences of the decision makers who wishes to make a reasonable choice by taking a better risk. Using a set of axioms for coherence among preferences, it shows the existence of utility function, defined on the set of choices and maintaining the individual's preference ordering. Also considering examples when a decision maker has to choose among the different kinds of utility functions to determine the maximum premium the policyholders have to pay to get a full coverage. The work also deal with the problems when several functions are proposed to obtain a necessary claim amount to be paid and a multi objective optimization procedure is used to obtain the appropriate parameters using statistical data of the company and to find the best function to approximate. The main goal of the paper is to find the best combinations of the applied methods to reach significant results in risk assessment.

3 - Warranty Provision for Repeatedly Purchased Experience Goods in a Duopoly Setting
Dmitri Nizovtsev

This paper studies the warranty provision in a duopoly market for an "experience' product, the true subjective value of which is initially unknown to buyers, in a setting when consumers intend to make repeat purchases. This case is compared to the durable goods case. Warranties in our model take the form of money-back guarantees (MBG). The problem is modeled as a non-cooperative game, where two firms' choices of quality, warranty, and price are endogenous. Whenever a pure strategy equilibrium exists, it is unique. In a pure strategy equilibrium, firms differentiate themselves in qualities and prices, but this vertical differentiation result rarely extends to the warranty space. In many cases, both firms offer full MBG contracts regardless of their product qualities. This result is different from the existing literature on the signaling effect of warranties. We attribute the lack of correlation between warranty and quality choices to the promotional role warranties may play in the presence of repeat purchase intentions and heterogeneity in consumers' experience with the good. We also find that both the number and frequency of repeat purchases affect the firms' equilibrium choices of qualities, prices, and warranty contracts. Overall, the research presented in this paper provides insight into the variety of warranty contracts, especially in the case when warranty is used as a promotional tool in a market for repeatedly purchased experience goods.

■ TC-30
Tuesday, 12:30-14:00 - John Anderson JA5.02, Level 5

Discrete-Event and Agent-Based Simulation

Stream: Simulation and Optimization
Invited session
Chair: *Horng-Chyi Horng*

1 - Development of shop floor capacity simulator application for Android OS users
Ahmed Allaith , Ammar Al-Bazi

This project aims to design and develop a capacity simulator mobile/tablet application for a quicker decision-making on manufacturing shop floor capacity issues. This simulator is running on Android OS and based on discrete event simulation methodology. Manufacturing shop floors are investigated by capturing the most critical variables that can be noticed in shop floors and have an effect on the processes. The research involved a literature review to identify the techniques, tools and issues within the field of shop floor capacity simulation, analysing industrial projects as the simulation project bases on their inputs and outputs and finally examining case studies of shop floors with related capacity issues to make simulation models more applicable to real life scenarios. The application intends to serve users to have an on-site visual capacity simulator tool for current and additional orders in shop floors. User who will find the application beneficial might be operation managers, production planners, capacity engineers and decision makers at the top management level. The project will essentially help to deliver a quick decision-making on-site simulation application regards capacity issues in shop floors. Currently, there is not similar on-site simulation calculators/applications. Overall, the project delivers a unique approach to solve shop floors capacity issues by providing an application of high quality serving the purpose of simulating capacity calculations.

2 - Integrating value stream analysis with simulation study to effectively improve production performance in a fitness equipment factory
Horng-Chyi Horng

The requirements of mass production in painting, the overturning of mold tools during welding, the specialty of testing tools, and the unique assembly sequences all increase the complexity of analyzing the overall system performance in the fitness equipment industry. How to shorten the production cycle time and to make the maximize productivity by integrating value-chain analysis and systems simulation will be briefly detailed in this paper by conducting a case study about the process of an individual fitness equipment company. This study first drew the value stream mapping from suppliers to customers for the three main products of the company. Then system simulation analysis tool was applied to construct simulation models. Finally, these models were validated via statistical analysis as compared to the actual system outputs. After validations, this study further applied the concept of Lean production to create future value stream mapping of these three products. Future value stream simulation model of the three products were also constructed. Simulation results of these models shown that they can effectively improve the utilization of enterprise resources as well as the overall production efficiency.

3 - Hybrid simulation of railway traffic in a complex dispatching area
Aseem Awad , Narayan Rangaraj

In this paper we tackle the problem of railway scheduling by a synthesis of agent-based and discrete-event simulation. Discrete-Event Simulation is a tool that has been used in the world of Operations Research for evaluating projects and situations for which field trials would be prohibitively expensive. However, the paradigm of agent-based simulation is not yet widely used in the OR community. We model a complex dispatching area as a network of connected resources upon which a discrete event simulation is run; however, the trains are modelled as agents that are capable interacting with one another and with the infrastructural elements. Thus we take the best of both worlds: From DES, the ability of modelling the flow of entities through a system and from ABS, the bottom-up modelling approach and the decentralized method of control. We use this simulator to simulate traffic on a typical junction of Indian Railways. The simulator is utilised for finding the best routing options and a feasible schedule.

■ TC-31
Tuesday, 12:30-14:00 - John Anderson JA5.04, Level 5

Big Data Analysis 2

Stream: Stochastic Modeling and Simulation in Engineering, Management and Science
Invited session

Chair: *Erik Kropat*
Chair: *Silja Meyer-Nieberg*
Chair: *Zeev (Vladimir) Volkovich*

1 - The analysis of the price difference between A-share and H-share markets
Yu Bai, Cedric Yiu

The price differences in segmented market for same company shares have been studied in the literature. For companies in China, they can be listed as A-share in the Shanghai Stock Exchange or H-share in the Hong Kong Stock Exchange. However, the A-H premium has been persistent since the launch of both shares. It is of interest to study the factors behind the price difference. This paper attempts to address this problem. We will focus on factor analysis and employ a variety of factors including fundamental factors, market factors, technical factors, and market microstructure factors. Based on the closing prices of 50 companies listed on both markets in recent three years, we employ the clustering technique to separate the price differences into groups. For each cluster, an appropriate factor model will be built. The result shows that different factors are required for explaining the A-H premium in different clusters. For example, the information asymmetry, trading liquidity, and market conditions are three prominent factors for high premium. Moreover, it is observed that the price differences are becoming narrow for many companies in recent years, which might pave the way to the final convergence.

2 - Batch Learning of Extended Self-Organizing Map for Mixed-Type Data
Chung-Chian Hsu, Kai-Ting Chuang

Self-organizing map (SOM) has been popularly used in cluster analysis and data visualization due to its capability of preserving topological order of the data after projection to a low-dimensional space. SOM can be trained incrementally or in batch mode. The original SOM algorithm handles only numeric data. An extended SOM was proposed which can process mixed-type data including numeric and categorical attributes. More importantly, in the extended model semantics embedded in categorical values can be reflected in the low-dimensional space. However, the previously proposed algorithm for the extended model was incremental. That is, the map was updated once with respect to each input instance. In this paper, we present a batch version of the training algorithm. Experiments on synthetic and real-world datasets are conducted to verify the proposed algorithm.

3 - A Data Mining Model for Medical Service Process Flow Prediction
Young Hoon Lee, Sun Hoon Kim, Farhood Rismanchian, Yongho Choi, Hyun Seop Uhm

A data mining model is studied for prediction of the medical service process flow. From real medical data, patients have been seen to perform different types of process flows depending on their characteristics. Clustering techniques have been investigated as the means to deal with this complexity by dividing cases into clusters. The sequence clustering techniques are applied as a kind of model-based clustering that partitions the patients according to their behavior. The methodology with probabilistic nature makes it suitable to be applied in this study which is involved in many different types of behaviors. The suggested procedure is utilized to develop medical process pattern clusters, and the clustering analysis is performed with real medical data.

◼ TC-32
Tuesday, 12:30-14:00 - John Anderson JA5.05, Level 5

AHP/ANP 07

Stream: Analytic Hierarchy/Network Process
Invited session
Chair: *Ellen Szarleta*

1 - Condition of Order Preservation and Inconsistency in AHP
Konrad Kułakowski

The analytic hierarchy process (AHP) is a widely recognized multi-criteria decision-making technique. It is based on comparing alternatives in pairs. The final ranking of alternatives is computed using the principal eigenvector of the matrix containing the results of all comparisons. A lot of research has been devoted to the critical analysis of the eigenvalue-based approach. An important voice in this discussion is the work (Bana e Costa and Vansnick, A critical analysis of the eigenvalue method used to derive priorities in AHP, EJOR, 2008), which defines the Conditions of Order Preservation (COP). In particular, the authors show that even for sufficiently consistent pairwise comparisons matrices, this condition cannot be met. The relationship between COP and inconsistency, however, has not been thoroughly discussed. In particular, an important question as to when COP is met (or not met) for a given level of inconsistency remains unanswered. The presented study is an attempt to answer this question. It reveals, in the form of appropriate theorems, the relationship between errors (understood as the discrepancy between expert judgments and the ranking results) and COP. Moreover, this relationship is extended to the local Koczkodaj's inconsistency index and COP, so that it becomes clear that lower inconsistency increases the chance that COP is met.

2 - Supplier Selection in Automative Industry Using Grey AHP Integrated Goal Programming
Ceyda Zor, Nilay Koyuncu Yemenici, Ferhan Çebi

It is vital for an enterprise to select the right suppliers to work with in the long-run, and is also important to buy the right material from the right supplier. The criterion for evaluating may be nominal or continuous variables. To evaluate nominal variables, the comparison judgements need to be expressed as ranges of numbers when vogueness or uncertainty in decisions is concerned. Grey AHP can be used in case of vogueness and evaluate linguistic variables. Goal programming (GP) is used to evaluate conflicting strategies and find a compromise optimum solution for the objectives of the firm. The result scores of Grey AHP is used as a utility function in GP so that nominal evaluation factors are taken into account while deciding; "Which supplier for which product?' This study is on a supplier selection problem in automative industry. Grey Ahp method is integrated to goal programming to evaluate suppliers in means of products. The difference of this study from earlier studies is that, some quality system requirements are added to objectives like defective rates. Also the algorithm does not permit the firm to make an order of the product to supplier, if there is an open corrective and preventive action on that product which has not completed by the supplier. The algorithm provides an integrated evaluation approach, which takes into account nominal variables with linguistic judgements of experts, the conflicting objectives of the firm and quality system requirements.

3 - Implementing AHP for Managing Environmental Problems: A Case Study at El Cocuy National Park.
Luis Echeverri, Julian Mendez, Jorge Romero, Juan Carlos Romero Gelvez

The management of environmental problems presented themselves to a complex problem, consisting of the interests and expectations of multiple agents characteristics. The purpose of this paper is to implement a methodology for addressing complex environmental problems by using multi-criteria decision aids. Problems in Colombian national parks are addressed through a case study applied in the Natural Park of Cocuy in Boyaca Colombia. The Park faces a number of problems represented in three categories: Environmental, Social and Economic, do not allow the sustainable development of both the surrounding communities and ecosystems in the region. This research and development of the model Analytic Hierarchy Process (AHP) is used to find the relevance of each problem and define the most important contributing to park management and conservation of ecosystems. The problems were identified by observation and bibliographic investigation, their prioritization was developed by means of judgment values of experts. Two of them with Phd. in ambiental sciences and tourism the last one is a park ranger that is a representant of the Sierra Nevada of Cocuy. Those judgments were found through polls and their tabulation was found by means of the software Super Decisions, discovering the aggregate relevance of the experts opinions, taking in to account their knowledge about each topic.

4 - Institutional Barriers to Applying AHP to Local Government Decision Making
Ellen Szarleta

Collective decision-making is essential for addressing the complex issues facing society. AHP's value in advancing decision-making processes is well understood by researchers and many practitioners. However, in the United States the method is often met with skepticism and

concern. Thus, the application of AHP is limited particularly at the local government level.

While the world is moving from fragmented to integrated decision-making our institutional structures are outdated. These structures do provide important safeguards for democratic engagement but do not facilitate collective decision-making processes. AHP challenges the democratic ideals of individuality, competition, and bureaucratic legitimacy.

In this paper, the institutional barriers to using AHP in local decision-making processes are identified and evaluated. The analysis employs a comparison of the assumptions underlying democratic decision making processes and those underlying AHP models. We propose that the legal framework supporting certain democratic decision-making processes creates barriers that left unrecognized, lead to inefficient collective decision-making processes. However, these barriers can be overcome once the policy implications of AHP decision-making processes are better understood.

Examining the views of local government officials toward AHP tools provides the opportunity to overcome the institutional challenges limiting its use. A case study will illuminate our points.

■ TC-33

Tuesday, 12:30-14:00 - John Anderson JA5.06, Level 5

Multivariate Quality Applications

Stream: OR in Quality Management
Invited session
Chair: *Ipek Deveci Kocakoç*
Chair: *Gul Okudan Kremer*

1 - Clustering Algorithm based Profile Pattern Recognition for Multivariate Process Equipment Data

Seung Hwan Park, Jun-Geol Baek

The profile analysis of the manufacturing process is critical to detect changes in the quality or equipment status of the process. In the manufacturing process, profile indicates the data having a predetermined shape during the process cycle. Various sensors of the process equipment in the state-of-the-art manufacturing processes such as semiconductor manufacturing process are to generate many types of profile data. In the actual manufacturing process, due to an increasing number of types of profile, the profile data is increasingly hard to be dealt with. Also, profile data includes a variety of characteristics (e.g. time-variant, nonlinear and multivariate). Therefore, this study proposes a two-step procedure considering various characteristics. First, this procedure is carried out to extract the profile features using the real-valued function that quantifies the similarity between two profiles. Secondly, extracted features are utilized to recognize the profile patterns by using clustering algorithm. Finally, for the verification of the proposed algorithm, we performed the reproducibility evaluation of the clustering algorithm and devised an experiment through the actual data to examine the field applicability.

2 - Diagnosis of Fabrication Process Equipment using Canonical correlation analysis

Seung Min Kim, Jun-Geol Baek

The semiconductor industry, is an advanced industry that leads the digital age. The demands for semiconductors are increasing rapidly. As the supply for the semiconductor industry increases, the importance of the semiconductor increases. Thus, it is crucial to supply the demand of the rapidly increasing semiconductor industry. The increase of research on yield and quality management is in semiconductor manufacturing process due to the increase in the importance of the semiconductor. In yield and quality management of the semiconductor, the equipment condition of the manufacturing process also affects the yield and quality. As a result, there is a lot of research conducted on the equipment status. Defects in the manufacturing process can only be detected when observed values are different from the trends or patterns that occur or exceeds the control limits. Thus, the maintenance process can only occur after a problem has been identified in the process. This study suggests variable selection based on correlations by using Canonical correlation analysis (CCA). In addition, prediction of the equipment condition is done using statistical models. This study enables the prediction of the faults in the process which brings benefits of increasing the yield and quality, and reduces the waste of raw materials and the unnecessary operations of the process equipment.

3 - Using Confirmatory Factor Analysis and Grey Relational Analysis as a tool in root cause determination in Six Sigma projects:

Nilay Koyuncu Yemenici, Ceyda Zor, Ferhan Çebi

The purpose of this study was to figure out that analysis techniques like CFA and GRA can also be used on 6 improvement projects when the causes of problem are latent variables and coefficient of factors are need to be compared.

Six sigma is an effective methodology that gained acceptance of many authorities today as a problem remover of the potential and current problems in processes. The problem handled in this study is customer order delays. Potential delay causes are determined by FMEA (Failure Modes and Effects Analysis), the interactions among causes and their contribution to root cause is analysed by CFA (Confirmatory Factor Analysis) and their effects on different product families is analysed by GRA (Grey Relational Analysis). The Grey relationship analysis is used to compare CFA results of different product families to determine whether the same causes are observed with similar effects. So the 6 improvement phase should be carried out on behalf of these, CFA helps us to determine causes and GRA helps us to determine scope of improvements.

■ TC-34

Tuesday, 12:30-14:00 - John Anderson JA5.07, Level 5

New Solution Advances

Stream: Computing
Invited session
Chair: *Gerhard-Wilhelm Weber*
Chair: *Andrzej Jaszkiewicz*

1 - Resource Efficient Computing: An Operations Management Approach

Felipe Abaunza, Ari-Pekka Hameri, Tapio Niemi

Nowadays data centers play an important role in modern society. Increased use of ever larger data centers has led to a high growth in the size of data centers, and therefore to an important increment of their energy consumption and carbon footprint associated with their operations. Although there is a large body of literature aiming at improving computing systems efficiency, there are few studies focusing on the use of operations management (OM) principles on computing resources. In this paper, we first identify which OM principles could be applied to improve the resource usage efficiency of data centers processing delay-tolerant jobs (e.g. scientific computing such as in the CERN data center). Second, we focus on the application of these OM principles: the law of variability, the law of utilization, and bottleneck management; we then show how these principles can be applied to computing resources. We illustrate this application by performing controlled laboratory tests. Results show that a better allocation of jobs, through the use of OM principles, could increase throughput and utilization of the system while reducing the amount of resources needed, including energy. Finally, we briefly discuss how these results could be combined with other techniques found in current literature to further improve the efficiency of data centers.

2 - Random vs. predefined weight vectors in multiple objective genetic local search — systematic experimental comparison

Andrzej Jaszkiewicz, Mansoureh Aghabeig

Many successful versions of multiple objective genetic local search use scalarizing functions with various weight vectors covering the whole set or a subset of the weights space. Some of the methods, e.g. MOGLS proposed by Ishibuchi and Murata and MOGLS proposed by Jaszkiewicz draw at random a weight vector for each iteration, composed of a single recombination and single local search. Other methods like MOEA/D proposed by Zhang and Li use a predefined set of well distributed weight vectors. There are arguments in favor of each of these approaches, but to our knowledge no systematic experimental comparison on combinatorial problems has been performed. In this piece of work we compare these two approaches for generating weight vectors on two problems — multiobjective TSP and multiobjective TSP with prizes.

■ TC-35

Tuesday, 12:30-14:00 - Colville C429, Level 4

Nonsmooth Optimization

Stream: Nonsmooth Optimization
Invited session
Chair: *Refail Kasimbeyli*

1 - Weak subgradient based solution method for nonsmooth nonconvex optimization
Gulcin Dinc Yalcin, Refail Kasimbeyli

In this study a new solution approach for nonsmooth and nonconvex optimization problems is introduced. This approach is based on weak subgradients of the objective function and does not require convexity on neither the objective function nor the set of feasible solutions. We present an algorithm for solving unconstrained optimization problems. The algorithm uses weak subgradients of the objective function at every iteration. Convergence properties for the solutions generated by iterations of the proposed algorithm are investigated.

2 - An algorithm for solving clustering problems in datasets with mixed attributes
Burak Ordin, Elvin Nasibov

Clustering is an important task in data mining. There are many algorithms such as the k-means, the global k-means for solving clustering problems in datasets with numeric attributes. However, there are only a few algorithms, such as the k-mode, for solving clustering problems in data sets with categorical attributes. Usually real world datasets contain both numeric and categorical attributes. Therefore, the development clustering algorithms for such datasets is very important. In this paper, we propose one such algorithm. It is based on the nonsmooth nonconvex optimization model of the clustering problem which allows one to significantly reduce the number of variables. Numerical experiments on real world datasets demonstrate that the proposed algorithm is efficient for solving clustering problems in datasets with mixed attributes.

Acknowledgements: We would like to thank TUBITAK for its support (Project Number:113E763)

3 - A conic functions algorithm based on incremental clustering
Gurkan Ozturk, Adil Bagirov, Emre Çimen

In this paper, a piecewise linear classifier based on polyhedral conic separation is developed. An incremental clustering approach is applied to find clusters in each class. Then conic functions are computed for each cluster using their centers. The final conic function separating two classes is computed as pointwise minimum of all conic functions computed using clusters from each class. The proposed classifiers is tested on real world large data sets. Results of testing are reported and the proposed classifiers is compared with many mainstream classifiers.

4 - A derivative free method in nonsmooth nonconvex constrained optimization
Refail Kasimbeyli, Adil Bagirov, Gurkan Ozturk

In this paper, a derivative free algorithm for solving nonsmooth nonconvex constrained optimization problems is proposed. This algorithm uses the sharp Augmented Lagrangian and is based on the combination of the modified subgradient and discrete gradient methods. The convergence of the proposed algorithm is presented and results of numerical experiments using wide range of nonlinear and in particular, nonsmooth constrained optimization problems are reported.

■ TC-36

Tuesday, 12:30-14:00 - Colville C430, Level 4

Applications of Operations Research in Education

Stream: Applications of Operations Research in Education
Invited session
Chair: *Seren Basaran*
Chair: *Ser Aik Quek*

1 - Multiobjective Classroom Timetabling in a University Center: Territorial Disputes, Methodology, Implementation
Paulo Oswaldo Boaventura-Netto, Valdir Agustinho de Melo, Diego Belay, Julia Cruz, Sandra Albernaz de Medeiros, Janaina Bilate, Samuel Jurkiewicz

The Humanities Center at a university was having difficulties with classroom allocation, as new courses started and increased the physical space demand. Two types of problems appeared: (a) the need of borrowed spaces in buildings outside the Center; (b) the habit of some center schools to make space reservations for their own use, requiring additional bureaucracies to external subjects in order for them to use "their" rooms. These two problems were mutually reinforcing: the territorial dispute diluted the room utilization and this strengthened the demand for outdoor spaces, which were eventually lent under time limitations and other constraints. The stress associated to these exigencies strengthened the care of these schools about retaining rooms for their use. To overcome this situation, an allocation model of rooms to groups of students associated with disciplines was developed. This work required a number of meetings between the developer team and people related to the problem and sensitive to the need for change. A metaheuristic guided by a multi-criteria objective function was used to seek good quality solutions. The criteria were the distances to be traveled by the students, the capacity gaps in the room occupation and the clearances to the total time available for each room. This model not only allowed a great work saving in the schedule preparation, but also made clear that much of the use of more distant rooms could be avoided with the end of territorial disputes.

2 - The Effects of Driving Experience on Responses to a Dynamic Hazard Perception Test
Mina Mahmoudi, Mahmoud Saffarzadeh, Masoud Tabibi

Novice drivers' lack of awareness, especially driver's license applicants, of potential traffic hazards while driving can cause dangerous situations and lead to an accident. In this study, through designing a dynamic hazard perception test consisted of 10 hazardous situations, a comparison between novice and experienced drivers in recognition of danger was made. The participants were comprised of 53 driver's license applicants and novice drivers and 34 experienced drivers. The inexperienced group reacted less quickly to potentially hazardous situations or even were not able to recognize them compared to experienced drivers' group. Cronbach's alpha was 0.847, there was good reliability. The results indicate that the novice drivers' awareness in recognition of potential traffic hazards needs to be raised before they join the cycle of traffic.It should be noted that this research was conducted with the support of the Research Center of Iran's Traffic Police "Rahvar" and the results are being reviewed for implementation.

3 - Teaching Graphical Linear Programming Using an Interative Spreadsheet
Ser Aik Quek

A programmed Excel spreadsheet is used to teach graphical Linear Programming interactively. For 2 decision variables, the spreadsheet will automatically graph up to 6 constraints in the correct order, together with the objective function line. The feasible direction for each constraint will be clearly shown. The feasible region is constantly shown, with the constraints involved indicated. With the click of a VBA button, the objective function line will be redrawn at the optimal vertex, displaying the graphical representation of the optimal solution. The objective function line may be manually and slowly shifted using 2 spin-buttons. If the objective function line is directly over the optimal vertex, dotted lines will indicate the optimal values for the two decision variables. This may be used to demonstrate each step of the Simplex Method. Each of the numerical value of the linear programming problem, including each coefficient of the two decision variables in the objective function and the constraints, as well as the right-hand-side of the constraints, may be gradually and separately changed in an animated fashion, with the graphical solution changing at the same time. Sensitivity analysis may thus be performed graphically for each numerical value of the problem. Another on-screen button allows a new problem to be scoped, by specifying the new number of constraints. The correct number of rows for data will be prepared for entering the new problem.

■ TC-37

Tuesday, 12:30-14:00 - Colville C411, Level 4

OR for Development and Developing Countries 1

Stream: OR for Development and Developing Countries
Invited session

Chair: *Elise del Rosario*
Chair: *Honora Smith*
Chair: *Gerhard-Wilhelm Weber*
Chair: *Andres Felipe Osorio*

1 - Use of Adapted Mixed Logit Model (MLM) for Solving BRT System Pricing Policy Problem in Sub-Saharan Africa

Joshua Magbagbeola

In Lagos State, BRT scheme is currently under review as a transportation control measure; research efforts are in top gear for this young but very effective tool of solving congestion problem. While this scheme may be effective for congestion reduction in central business district (CBD), provision of alternative means of transportation for the "pushed-out" auto users is of great importance to obtain public acceptance. Hence, it is necessary to simulate simultaneously the area pricing scheme and the BRT development which may serve as an alternative for assumed pushed-out auto users. Utilizing data from the available opinion survey, this paper studies how BRT and auto ridership are likely to vary as a function of travelers and system attributes. Additionally, the study attempts to evaluate the way this new travel mode is distinguished from other existing conventional transportation alternatives in Lagos State. Respondents were then asked about their willingness to shift from their current mode to BRT to make the same travel for different BRT fare levels. Modeling efforts suggest that a mixed logit model performs better in explaining choice behavior. Therefore, this model was used for policy simulation. The simulation results brought about many implications as to the tested policies. While the developed model may be applied only to existing BRT corridors in which the survey was conducted.

2 - The Proliferation Threat as a Part of Sustainable Development Index

Kseniia Ilchenko

The sustainable development's modeling needs to consider influence of global threats into the balance of its dynamics. Some of these threats: the debarment of the nuclear war, terrorism and the decreasing of total number of weapons can be described through proliferation. Taking into account the sophisticated meaning of this category, it is impossible to measure it by monitoring the weapons' spread around the world. However, the political and strategical decision making processes in sustainable development establishment need quantitative argumentation. Therefore, the model that describes the proliferation as a complex global threat and can show values for comparative analysis of states dynamics was drawn out. The proliferation threat hierarchy model includes four subgroups and 25 indicators which are described by corresponded data sets. In accordance to data limitation, the proliferation threat was calculated for 136 states and territories. The proliferation threat was included to Index of Sustainable Development as a factor with negative influence. But It is necessary to mention, that it can be used for purposes of forecasting and states' rating creation as a separate model.

3 - Exploring Effects of Destination Image on Word of Mouth and Responsible Tourist Behaviours: A Case of Jiaosi Township in Taiwan

Shan Ju Chi, Yung Kuei Huang

The literature has suggested that destination image leads to tourists' satisfaction as well as willingness of revisit. In view of the increasing need for sustainability and responsible tourism, research on destination image should go beyond the marketing-oriented scope. As such, the relationship between perceived destination image and tourist behaviours directed at promoting and protecting a destination deserves greater scholarly attention. More specifically, this study will focus on word-of-mouth and responsible tourist behaviours. The purpose of this study is to investigate the effects of image-related attributes, such as perceived destination uniqueness, attractiveness, functional benefits,

holistic image, and social prestige, on word-of-mouth and responsible tourist behaviours among Taiwanese tourists visiting Jiaosi in Yilan, Taiwan. Jiaosi is selected for this study due to its famous hot springs and fast-growing tourist numbers. In recent years, temperature drop and a decline of the hot-spring water table in Jiaosi have gained attention publicly. A cross-sectional survey design will be adopted to address the proposed relationships in this research. Confirmatory factor analyses and structural equation modeling will be performed to analyze collected data. Anticipated findings will add to the literature on destination image and tourist behaviour, providing insights into managing and branding a destination in a sustainable fashion through engaging tourists.

4 - Lower is not always Better: Shedding Light on the Debate about Optimal Administrative Cost Ratio Levels for NPOs

Christian Burkart, Tina Wakolbinger, Fuminori Toyasaki, Michael Fearon

Assessing the performance of an NPO proves to be a challenging task. Using administrative cost ratios to total donations as a proxy for efficient usage of donations can lead to undesired side effects. These include incentives to lower administrative cost ratios down to levels that cannot sustain required administrative capacities. This phenomenon known as the 'NPO starvation cycle' results from a downward spiral of NPOs competing for donations via low administrative cost ratios and increasingly low ratio expectations from donors, increasing downward pressure even further. In this paper, we develop a modeling framework to analyze the influence of the consideration of administrative costs on the decision-making behavior and utilities of NPOs and beneficiaries. Starting from a general analytical optimization framework, a set of extensions is considered, incorporating different influential factors, including the organizational size of the NPO, the level of information concerning administrative costs available to the donors and varying amounts of donation potential that could possibly be solicited. Our results indicate that the level of donations has no influence on the optimal level of administrative cost ratio, while the information level has a negative impact on this ratio as well as on the utility created in an environment of high marginal efficiency gains of administrative expenditures.

■ TC-38

Tuesday, 12:30-14:00 - Colville C410, Level 4

Quality and Performance Measurement in Humanitarian Relief Chains 1

Stream: Quality and Performance Measurement in Humanitarian Relief Chains
Invited session

Chair: *Sadia Samar Ali*

1 - University Timetabling via Goal Programming

Veronika Skocdopolova

Goal programming is a widely used approach for solving not only multi-objective decision problems. It is 60 years when the goal programming was first formulated. Since that time it becomes very popular technique that has many real-world applications. Problem of university timetable construction is NP-hard problem that each university deals each term with. Some of them use time-tested scheduling board, the other use more or less sophisticated computer-based system. The University of Economics, Prague, belongs to the first group. The problem of this process is that the timetable from the previous year is only modified a little bit. Therefore the timetable does not react on specific changes between the two academic years. This paper presents a complex model, which utilizes goal programming with penalisation function for solving the timetabling problem. The complex model takes into consideration the specificity of timetable of the department of econometrics at the University of Economics, Prague. It also deals with teachers' time preferences.

2 - Exploring Green supply chain performance measures framework for Indian Manufacturing Practices

Sadia Samar Ali

The world has come a long way from the time of abundant and affordable energy to a time of limited and expensive energy. It is the need of the hour to preserve the lead resources and in the wake of the need for environmental protection, logistics and supply chain managers are required to reduce costs while maintaining good environmental performance standards. Manufacturing firms around the globe are opting for cradle to cradle products that are more energy efficient and environmental friendly. Henceforth, it is now essential that all processes in the supply chain rely on resources that are cost effective and incur minimum cost possible. Researchers started on focusing on the green supply chain management (GrSCM), reverse logistics, in particular, closed-loop logistics in the wake of the growing concerns about global warming and alarming consistent increase in amount of e-waste (comprising majorly of end-of-life ,EoL) electronic and electrical products. Green supply chain management GrSCM ensures the optimal use of resources by integrating the concept of disposal, recycling, reusing or remanufacturing of the product or its parts .Here researcher has developed a theoretical framework on identified constructs that are undergoing for Green Supply Chain Management practices with the effect of environmental aspects on supply chain management.The purpose of this paper is to explore the antecedents of Indian firms practicing green supply chain management on firm performance.

■ TC-39

Tuesday, 12:30-14:00 - Colville C405, Level 4

DSS Supported by Simulation and Optimization Approaches

Stream: Decision Support Systems
Invited session
Chair: *Fatima Dargam*

1 - Decision analysis of contractual misincentives to support optimal ITO agreements
Ana Paula Costa, Thyago C. Nepomuceno

We use Agency Theory to argue that due to a non-linear relationship present in the cost structure of software vendors, caused mostly by side effects in the code development phase, and as a result of asymmetry in information, decision making by a client to impose penalties onlate delivery or low-quality products in information technology outsourcing (ITO) agreements must, in most situations, encourage those irregularities instead of prevent them from occurring. We work on a contract theoretical model with no penalty in the first instance to show that the agent (a software vendor) has no reason to deviate from the first agreement to neither delay nor anticipate delivery. After this first moment, we draw a game involving a certain fine associated withan irregularity, and then we derive the new first best response, including the penalty variable, to prove that in some situations, it could be a mistake for the client to impose a penalty on attributes thatmight perform as a misincentive for the vendor. Our results were based on both a mathematical analysis and from empirical evidence of data inITO contracts of software services signed among thestate organizations of Portugal's government duringthe year of 2013 to 2015, and made us conclude that the asymmetric information in the perception of cost structures is responsible for this kind of behavior in outsourcing contracts with punishment clauses.

2 - Decision Support System (DSS) for Econometric Department's Performance Metrics in Turkey
Aslı Özmen

Integrating performance measurements for the education system is not an easy task because of defining criteria and measuring standardizable outcome with different scale. In this research multi criteria decision aid tools are used for performance measurement. Educational metrics are designed with the use of National Qualifications Framework of Turkey (NQF). NQF is a system in which qualifications recognized by national and international stakeholders are structured within a certain organization. Through this system, all qualifications for higher education and other learning outcomes can be explained and related to each other consistently. (Turkey Higher Education Council). The performance evaluation of the departments (it also means macro point' universities') in terms of educational management is a complex process, in which multiple criteria are required to be considered simultaneously. To achieve this point, it is considered a fact that selecting and weighting education metrics are essential. Subjectivity is generally considered as the main problem for multi criteria decision aid techniques. Dispelling this point, different outranking techniques are used (Entropy, Protmethee I-II, Electe, Topsis, Vicor) in this study. This study's main contribution is not only to find the best solution, but also to build a framework (DSS) for decision makers and thus helping the system for their goals and shaping their decisions.

3 - SIGMO: A Decision support system for genetically modified feed and food detection
Biljana Mileva-Boshkoska, Marko Bohanec, Theo Prins, Esther Kok

One of the increasing cost factors in the food supply chain in the EU is detection of imported genetically modified food and feed products (GMFF). To support the decision making process for analysis of GMFF by the involved stakeholders, we have developed a decision support system (DSS) called SIGMO within the frame of the EU FP7 project DECATHLON (DECATHLON FP7-KBBE-613908, 2013-2016). The proposed DSS contributes in the process of cost and risk reduction for different analyses related to the identification of (unauthorised) GM ingredients in food supply chains. SIGMO is designed as a combination of data-driven and model-driven DSS. It contains two main internal components: a data base providing data about GM crop species produced and events approved in counties worldwide; and a qualitative multi-attribute model for the assessment of GMO presence in food/feed products based on traceability and analytical data. The model is developed using the methodology DEX and freely available software DEXi that supports the development of DEX models and evaluation and analysis of decision alternatives. To provide a user-oriented operationalization of SIGMO, the DSS is implemented as a web-based solution. It consists of three pages: an input page where the user enters the data for assessment, an output page which provides the results of the evaluation, and a print page suitable for saving the results. SIGMO will be used by stakeholders as an onsite tool for detection of dedicated GMFF.

■ TC-41

Tuesday, 12:30-14:00 - Colville C512, Level 5

Non-additive Integration in MCDA I

Stream: Multiple Criteria Decision Aiding
Invited session
Chair: *Brice Mayag*

1 - Advances on Choquet integral for maps comparison
Valérie Brison, Marc Pirlot

The Choquet integral is used in the field of multi-criteria decision aiding to represent preferences when there are some interactions between the criteria. In our work, we use the Choquet integral in order to take into account the contiguity between geographic units when comparing maps. More precisely, we want to help a decision maker to compare maps representing the state of a region at different stages of its evolution. The maps are divided in geographic units which are assessed on the same ordinal scale. In some cases, the value of a unit can be influenced by the value of the units located in its neighborhood. This aspect can be represented by means of a Choquet integral which can be axiomatized and elicited.

2 - Stochastic Multiobjective Acceptability Analysis for the Choquet integral preference model and the scale construction problem
Silvia Angilella, Salvatore Corrente, Salvatore Greco

The Choquet integral preference model is a non-additive integral very well-known in Multiple Criteria Decision Aiding (MCDA). Differently from the usual additive value functions being based on the mutual preference independence of criteria, the Choquet integral models preferences that violate this assumption and it is able to handle positive and negative interactions. Two are the main drawbacks known for this aggregation method: the elicitation of the capacity or fuzzy measure on which the Choquet integral is based and the construction of a scale common to all evaluation criteria. On one hand, we shall consider the indirect technique in which the Decision Maker (DM) is able to provide some preference information from which some capacity could be inferred. Several capacities could be compatible with these preferences and choosing only one of them could be considered arbitrary and meaningless. On the other hand, in order to apply the Choquet integral preference model, the evaluation of the alternatives on the considered

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criteria have to be compared on the same scale. To deal with both problems, we propose to apply the Stochastic Multiobjective Acceptability Analysis (SMAA), an MCDA technique, which uses probability distributions on the capacity and evaluation space to give robust recommendations for the problem at hand.

3 - Normative properties of the superposition of multi-criteria choice procedures.
Sergey Shvydun

We study the superposition of different multi-criteria choice procedures such as scoring rules, rules, using majority relation, value function and tournament matrix, which are used in social and multi-criteria choice problems. The main focus of the work lies in the study of normative properties (rationality, monotonicity, non-compensablity) for 591 different multi-criteria choice procedures. Such information leads to a better understanding of different choice procedures and how stable and sensible is a set of alternatives obtained after applying some choice procedure. We also divided multi-criteria choice procedures in accordance with their computational complexity and obtained a list of those procedures which can be used in Big Data analysis.

4 - An extension of Electre III for dealing with a multiple criteria environmental problem with interaction effects between criteria
José Rui Figueira, Marta Bottero, Valentina Ferretti, Salvatore Greco, Bernard Roy

Many decisions can be affected by certain types of interaction effects between some criteria, as for example, those resulting from a synergy or a redundancy phenomenon. However, in real-world decision aiding situations the relevant interactions are those that generally occur only between a small number of criteria pairs. Presently there is only a few number of methods to deal with such interaction effects. The interaction between pairs of criteria is important when assessing sustainable development. The purpose of this paper is to study the applicability of the Electre III method with interaction between pairs of criteria. We are interested in the ranking of five alternative projects, compared on six criteria, for the re-qualification of an abandoned quarry. A focus group of experts has been constituted with the aim of being in charge of the process leading to the assignment of numerical values to the weights and the interaction coefficients. We relate on the way the process evolved and on the difficulties that we have encountered to obtain consensual sets of values. Taking into account these difficulties we have considered other sets of weights and interaction coefficients. Our aim was to study the impact on the final ranking of the fact that these numerical values, assigned to the parameters, were not perfectly defined. This allowed us to formulate robust conclusions which have been then presented to the members of the focus group.

■ TC-42
Tuesday, 12:30-14:00 - McCance MC301, Level 3

OR in Civil Government 1

Stream: OR in Civil Government
Invited session
Chair: *Vivienne Raven*

1 - Is the traditional, Public Sector policy making cycle still fit for purpose?
Ben Follows, Will England

For many years, central analytical teams in HMRC have established themselves as units of expertise in areas such as impact and process evaluation: for example using Random Control Trials (RCTs), to drive decision making and measure success. As the government digital agenda builds momentum, we see the decision making cycles spinning at an ever increasing rate. Coupled with this, transparency & accountabily for operational delivery has never been higher, driven in part by the introduction of Lean ways of working. For the traditional evaluation teams, this poses substantial challenges, for example in extreme cases commitment and accountability for future delivery has been set before project/programme designs are finalised and in-turn this undermines the influence of any post-hoc evaluation design. This presentation explores these evolving decision making styles in HMRC and how central analytical teams have starting to respond to the challenge; including using a combination of OR, Statistics and Social Research approaches. We'll also explore the reasons that why, despite the inherent

challenges, the design and implementation of robust RCTs, AB testing and post-hoc evaluation has never been more important for HMRC operational decision making and performance measurement.

2 - Risk Scores: using predictive analytics to reduce Fraud and Error in UK benefits
Christine Peachey-Pace

You may be familiar with the concept of credit risk scores; banks use information on your personal and financial circumstances to decide how 'risky' it would be to lend you money. Similarly the UK's Department for Work and Pensions use risk scores to determine how 'risky' a welfare benefits claim is, that is, how likely is it that the claim will contain an error caused by the claimant? Unlike banks, the Department does not refuse welfare benefits due to the output of these predictive models, but they are a key tool for directing limited resources towards checking and reviewing claims which are most likely to contain an error. This presentation will give an overview of the different modelling techniques explored in developing risk scoring models and how the 'best' model for the job is chosen with reference to how the recommended model can change based on the customer's final/changing requirements.

3 - UK Search and Rescue Helicopters
Robert Palmer

In 2013 the Department for Transport awarded a £1.6bn contract to Bristow Helicopters Ltd to provide Search and Rescue services for ten years from 2015, using state-of-the-art Sikorsky S92 and AgustaWestland AW189 helicopters from ten bases around the UK coastline. The Operational Research element of the procurement project was crucial for the robust evaluation of bids, enabling the Department to assure itself that bids could meet its requirements for the delivery of this life-saving UK-wide service. This talk will describe the 'Competitive Dialogue' procurement process and the modelling work used to evaluate bids and support the case for the new service.

4 - Intelligent Designs - Systems approaches to understand Policy Rationales and Objectives
Ian Mitchell

The delivery of policy benefits from a systematic approach. Operational Research techniques for Problem Structuring have immense potential to develop such approaches.

The delivery of policy benefits from a systematic approach. Operational Research techniques for Problem Structuring have immense potential to develop such approaches.

The paper introduces the policy context in theory and practice for Operational Research projects supporting the early stages of policy delivery. Logical Rationale and sensible Objectives are the foundations for resilient Appraisal and implementation of policy with evaluation and constructive feedback.

Problem Structuring Methods are offered as distinctive Operational Research contributions. The paper considers the complementary benefits of Soft Systems Methodology, System Thinking and Multi Criteria Decision Analysis illustrated by recent experience in Whitehall and at the most local levels of government.

The earlier that these Operational Research techniques are applied the more intelligent the design of the policy. This enhances the likelihood of achievement of effectiveness and efficiency.

■ TC-43
Tuesday, 12:30-14:00 - McCance MC303, Level 3

Supply Chain Optimization

Stream: Production and the Link with Supply Chains
Invited session
Chair: *Farouk Yalaoui*
Chair: *Jonathan Oesterle*

1 - A Study of Supply Chain Integration Initiatives' Impact on the Relationship between Supply Chain Complexity and Firm Performance

Hyun Jung Kim

Companies have become increasingly complex as industries have advanced. In turn, supply chains have also become more complex, with businesses responding to environmental changes by forming strategic alliances or outsourcing to enter new markets and launch new products. Therefore, supply chain complexity has received much scholarly attention. Previous studies, however, have several limitations. First, most studies have focused on elucidating the negative effects of supply chain complexity on firm performance while overlooking that a certain level of supply chain complexity is intrinsic. Second, research on how companies should manage supply chain complexity is lacking. Although several studies have proposed supply chain integration as a way to manage complexity, its impact has not yet been empirically tested. Therefore, this study aims to expand on prior studies by examining not only the negative impacts of complexity on firm performance but also any positive impacts. In addition, this study aims to explicate how companies can effectively manage supply chain complexity. This study offers the following theoretical implications. First, a new perspective is presented for investigating the effect of supply chain complexity on firm performance. Second, this study makes a significant contribution by identifying the appropriate combined relations among each supply chain complexity and supply chain integration component.

2 - Fleet deployment, selection from different transportation modes, costing policies and contract types incorporated into the same supply chain model

Thanos Pappas, Dimitrios Lyridis

Extending and improving an earlier work of the second author this paper formulates the incorporation of several transportation modes with different costing policies and contract types into the same supply chain model and attempts to optimize the fleet deployment strategy in terms of the minimum transportation cost. In other words it attempts to give a practical solution to large companies with complex supply chain networks that have to deal with various carrier types with different features and constraints, different costing policies and contract types. This is achieved by creating a pool of all different transportation types (vessels, trucks, railway etc.) and classifying them with all their relevant attributes (capacities, availabilities, freights, contracts types, constraints etc.) into specific database tables, efficiently developed so as to constitute input to any supply chain model. With this respect this partial modelling is being embedded into a complex supply chain model, possible scenarios are simulated and corresponding results are examined. The background and the literature in fleet scheduling is reviewed and the objectives and assumptions of our approach are explained.

3 - Supply Chain Complexity Measurement in the Semiconductor Industry: A Discussion of Influencing Factors and Changes in a System

Can Sun, Thomas Rose, Thomas Ponsignon

The global semiconductor and high-tech supply chain is very sensitive to the changing macroeconomic environment due to the volatile electronic market and the hard-to-predict demand. These changes inevitably result in complexities and challenges for supply chain management (SCM). From the perspective of its internal mechanism, SCM in semiconductor needs to handle complex manufacturing processes and a wide variety of products by nature. Methods for complexity analysis currently focus on the sources and drivers. Yet, quantitative methods for assessing complexity are not well established. Decision makers would like to translate complex information about systems into formal metrics for measurement. We believe that the system complexity is affected by factors both outside and inside of a problem domain. Therefore, this paper aims to answer particular questions towards complexity assessment: how to measure influencing factors of supply chain complexity and how to incorporate them into mathematical models. Our strategy is to build a general three-layer model for complex systems and specify the features for each atomic element at the bottom level. The influencing factors and their impacts are detected based on this model. Human factors including the goals, conflicts, attitudes, skills are also highlighted. Agent-based simulation is explored as an efficient tool to model them. We thus propose the metrics of complexity measurement and demonstrate a tradeoff between complexity and cost.

4 - Improvement Practices in Construction Supply Chain Management

Georgios Papadopoulos, Nadia Zamer, Sotiris Gayialis

In a very competitive and complex industry like the construction industry with demands for the delivery of top quality projects at very competitive prices, a significant need for an effective management of the construction supply chain has arose. Construction Supply Chain Management (CSCM) is a very promising approach to successfully achieve integration between the several disciplines of the chain (internal and external suppliers, designers, vendors, subcontractors, clients). Even though SCM in the manufacturing industry has been widely researched and developed, the application of the same concepts to the construction industry shows problems in construction supply chains are extensively present and persistent. Analysis of these problems has shown that a major part of them originate at the interfaces between the various disciplines or functions and the complex nature of the construction environment. The aim of this research study report is to provide a set of propositions for improving construction supply chain management such as benchmarking, improvement of suppliers/subcontractors performance, elimination of waste, training and information sharing between parts of the supply chain. The study includes the literature review regarding the trends of the CSCM, the specific characteristics and problems in coordinating supply chain and finally it suggests improvements in supply and demand management by suggesting specific practices to be implemented.

■ TC-44

Tuesday, 12:30-14:00 - McCance MC319, Level 3

Fuzzy Systems I

Stream: Fuzzy Optimization - Systems, Networks and Applications
Invited session
Chair: *Ozan Kocadağlı*

1 - The effect of uncertainty of the processing time on the optimal solution in the job shop scheduling problem

Abdalla Ali, Phil Hackney, Martin Birkett, David Bell

In this paper we study the effect of uncertainty of the processing time on the optimal solution for job-shop scheduling problem with criterion of minimising the total tardiness. Genetic optimisation process is applied to find an optimal solution with deterministic processing time. The Monte Carlo simulation is then carried out to quantify the probability of failure of the system with respect to the total tardiness. Triangular fuzzy processing time to generate the processing time for each operation is used in order to obtain the distribution of probabilistic processing time. The total tardiness is calculated for each distribution and the results are evaluated to have better understanding on the effect of uncertainty of the processing time on the optimal solution in the job shop scheduling problem.

2 - Pareto optimal solutions of multi-objective linear fractional programming problem with interval coeffi

Akshay Ojha

Numerous problems associated with real world decision making situations are mathematically modelled into multi-objective linear fractional programming problems (MOLFPP) which comprise many objectives existing in form of fraction of two other functions and need simultaneous optimization under a common set of constraints. There exists no single solution which can optimize all the objectives together with their own best satisfactory level as their respective individual optimal solutions do,so the pareto optimal solutions are derived from which the decision maker (DM) chooses the most preferred optimal solution. A procedure is illustrated to generate pareto optimal solutions of a MOLFPP with closed interval coefficients of decision variables both in objective and constraint functions. Certain rules including the concept of interval arithmetic are followed which transform coefficients of interval forms into real values and epsilon-constraint method along with a variable transformation technique is applied to produce a set of pareto optimal solutions comprising most preferred solution to satisfy all the objectives with best possibility. In order to justify and demonstrate the proposed method, a comparision is made in between the results obtained from a numerical example due to our method and existing fuzzy max-min operator method.

3 - Contrasting a Particle Swarm Optimized Radial Basis Function Neural Network with a Generalized Additive Neural Network for Detecting Unsolicited Email Messages
Tiny Du Toit, Hennie Kruger

Particle Swarm Optimization (PSO) has matured from a mere curiosity some years ago to a technique that interests researchers around the world. With PSO a number of particles are placed in the search space of some function or problem. For each particle the given objective function is evaluated iteratively at its present location until the swarm has moved close to an optimum of the fitness function. A Radial Basis Function neural network (RBFNN) is an universal approximator with each hidden unit having its own centroid. For every input it computes the distance between the input and its centroid. The output is then some non-linear function of all these distances. Generalized Additive neural networks (GANNs) are relatively unknown and it is the neural network implementation of a Generalized Additive Model. It has shown promise in many areas including the classification of unsolicited email messages. In this study a RBFNN is optimized using PSO for identifying unsolicited email messages and then compared to a GANN in terms of the Total Cost Ratio metric. Three publicly available spam corpora are utilized and the results and insights obtained will be discussed.

4 - Time Series Forecasting using Full Bayesian Approach of Artificial Neural Networks
Ozan Kocadağlı

The aim of this study is to propose an evolutionary Monte Carlo algorithm for Bayesian neural networks in the context of time series forecasting. This novel approach is based on the full Bayesian learning, and integrates Markov Chain Monte Carlo procedures with genetic algorithms and the fuzzy membership functions. In the application section, the proposed approach is compared with the traditional neural networks and time series techniques in terms of their estimation and forecasting performances over the sample data sets.

■ TC-45
Tuesday, 12:30-14:00 - Graham Hills GH514 Lecture Theatre

Transport Network Design

Stream: Optimization of Public Transport
Invited session
Chair: *Juan A. Mesa*

1 - Competition Effects and Transfers in Rail Rapid Transit Network Design
Luis Cadarso, Manuel Fuentes, Ángel Marín

Increasing mobility and longer journeys caused by the growth of cities have stimulated the construction and expansion of rail rapid transit systems such as metro and light rail systems. The design of these systems depends on future passenger usage. Transportation demand models are usually used to develop forecasts of passenger demand for each origin-destination pair. Then passenger choice models are used to estimate for each origin-destination pair the proportion of demand each operator captures, which depends on certain attributes. Frequency, fare and travel time are some of the most important attributes. Another convenient attribute for attracting passengers is to offer direct trips without transfers. Transfers are usually extremely discouraging. Both, travel time and transfers strongly depend on the network design. Therefore, it is extremely important to account for them in order to make an efficient design. We present a mixed integer non-linear programming model for the rapid transit network design problem that includes a passenger choice model to capture multi-modal competition. We develop a new formulation which embeds a logit model for modeling passenger behavior and introduces transfers in the modeling approach including the transfer cost in the passenger trip generalized cost. We solve this model using Lagrangian Relaxation to obtain the optimal solution to realistic problem instances obtained from the network of Seville in Spain.

2 - Heuristics for Skip-Stop Public Transport Scheduling Problems
Joanne Suk Chun Chew, Heng-Soon Gan

Public transport scheduling problems, as reported in the literature, are often tackled using generic methods such as mathematical programming techniques, metaheuristics and evolutionary algorithms. As a complementary contribution to the literature, we have considered heuristic approaches to a public transport scheduling problem variant. The problem at hand assumes morning peak, where all stations are pick-up locations and there is only one destination (located after all pick-up locations) for all passengers. The transportation vehicles are allowed to skip stations. We investigated variants of this problem with a single objective (total waiting time or total travelling time). The following problem attributes are considered: interfering (overtaking) and non-interfering (non-overtaking) schedules, and equal and non-equal passenger sizes. Optimal algorithms are developed for the total travelling time minimization problem, and the total waiting time minimization problem with equal passenger sizes. Other attributes of the total waiting time minimization problem are solved using efficient heuristics, and empirically shown to produce high quality solutions.

3 - Demand-based network design problem
Yousef Maknoon, Shadi Sharif Azadeh, Michel Bierlaire

Demand-based network design refers to the class of scheduling problems in which OD demand flow is subjected to individual choice. As a result, the operational decision should explicitly take into the account individual behavior as well as operational cost.

In this presentation, we show the general elements of these problems and distinguish them from other scheduling paradigms. We also present its application in multimodal transportation system and show that how the integrated model of supply and demand can achieve a better solution.

4 - On the complexity of transportation network design with alternatives
Juan A. Mesa, Mozart Menezes, Federico Perea

In this paper we discuss on the computational complexity of transportation infrastructure network design problems, in the presence of a competing transportation mode. All problems studied have a common objective: the maximization of the number of travelers using the network. The differences between them are due to two factors. The first one is the constraints that the new network should satisfy: budget constraint, no-cycle constraint, and both of them. The second factor refers to the topology of the underlying network, over which the new one is to be built: a general network, and a forest. So, in total we analyze six problems, five of them are shown to be NP-hard, and the other is trivial.

■ TC-47
Tuesday, 12:30-14:00 - Graham Hills GH513, Level 5

MAI: Academic-practitioner collaboration round table 1: Expectations

Stream: Making An Impact 1 (MAI 1)
Invited session
Chair: *Galina Andreeva*
Chair: *Stephen Lorrimer*

1 - Academic-practitioner collaborations: round table 1: Expectations from each side
Stephen Lorrimer, Gregor Brandt, Laura Reid, Thomas Archibald, Cathal Brugha, Simon Taylor

This is the first of two academic-practitioner round tables. Each of the two sessions will involve an exchange of views on academic-practitioner collaborations with the objective of designing a blueprint for successful partnerships. The discussion will be led by a panel of academics and practitioners with extensive experience in collaboration. After brief introductions from the panel, the audience will be invited to ask questions and share the views on some of the following topics (the list is not exhaustive): Round table 1: expectations from both sides ● Expectations and potential benefits from each side; ● Problems and challenges; ● Lessons learnt from successful collaborations; ● Lessons learnt from unsuccessful collaborations.

■ TC-48

Tuesday, 12:30-14:00 - Graham Hilils GH510, Level 5

Facility Layout

Stream: Location
Contributed session
Chair: *Haldun Sural*

1 - Facility layout problem in an irregular logistics park
Yanru Chen, *Yangsheng Jiang*

Facility layout problem (FLP) in a Logistics Park (LP), which involves the optimal placement of a set of functional areas with known dimension, differs from traditional FLP because obstacles, such as railways or highways, may cross the LP. LPs also commonly have an irregular instead of a rectangular shape. These additional features make FLP in an LP (FLP-LP) more complex and require explicit modeling. This paper presents a two-stage framework to find competitive solutions to this layout problem. The first stage involves using the clustering technique to allocate the functional areas into sections based on obstacles. The second stage involves determining the layout of the functional area in the respective sections by combining slice structure and irregular objects. Numerical examples demonstrate the effectiveness of the proposed framework.

2 - A heuristic method for storage location assignment problem for a distribution center
Zeynep Turgay, *Necati Aras*

Storage location assignment (addressing) of products is an important research topic in warehouse design. In this study, we solve storage location assignment problem for a distribution center providing day-to-day service for a retail chain. Orders are received from the stores and each order has a random number of products with random quantities. Order pickers collect the products ordered by the stores from their addresses and deliver to the order shipment area. The objective is to optimize the total effort spent by the order pickers in terms of the total traveling distance (or time). The most widely used method in the literature is the cube-per-order index policy (COI). Even though it is simple to implement, the COI policy relies on strict assumptions. Since, a distribution center of a retail chain may have significantly different characteristics from these assumptions, the use of COI policy may lead to suboptimal results. In this study we propose a different indexing policy based on relative ordering frequency and joint relative ordering frequency of items, and also develop improvement heuristics for the same problem. We demonstrate the effectiveness of our proposed method on real data and also show that it improves the results obtained by classical methods such as COI and ABC analysis by up to 25%.

3 - The integrated facility layout problem
Begun Efeoglu, *Haldun Sural*, *Melih Çelik*

Recent trends show that existing layout configurations do not meet the needs of multiproduct enterprises and that there is a need for facility layouts that are flexible, modular, and easy to reconfigure. We investigate the effect of the stochastic demand, described by jobs having different sequences of machine types, and the cost of relayout on the choice of a layout type (distributed, reconfigurable, robust, dynamic layout). We study the case of limited machine capacity and multiple copies of each machine type. The problem is formulated as a two-stage stochastic integer program with the objective of minimizing the total transportation cost over all scenarios. We simulate the solutions of randomly generated problems to study the tradeoff between total cost and lead time in the system. Our experimental results indicate that distributing the department duplicates throughout the facility reduces the total cost and causes increasing lead time.

■ TC-49

Tuesday, 12:30-14:00 - Graham Hills GH511, Level 5

Airline and Flight Operations

Stream: Airport Operations and Airline Scheduling
Invited session
Chair: *Andrew J. Parkes*
Chair: *Daniel Karapetyan*
Chair: *Jason Atkin*

1 - Tactical Competition of Two Airlines in Fleet Assignment
Taner Bilgic, *Ceyda Yaba*

We analyse two airlines competing in the same market at a tactical level using an itinerary-based fleet assignment model. The market demand is contingent on the fares chosen by the airlines. The airlines solve their own fleet assignment models and can choose to spill customers on some itineraries. The recapture rates of these customers are also contingent on the fares chosen by airlines. Therefore the dimensions of competition are both the demand and the recapture rates in the same market. Using a logit model for allocating the demand and the recapture rates between the airlines we seek for equilibrium behaviour of the airlines with exogenous fares in a computational setting. We argue that in this tactical level competition, variables like fleet type and aircraft capacity are as important as the fares.

2 - Solving the Airline Overbooking Problem Using Fuzzy Optimisation Techniques
Berkcan Uyan, *Ammar Al-Bazi*

It is essential to cut costs and increase revenue wherever is possible in an airline business. To increase revenue, revenue management (yield management) is used in airline industry to maximise the profit through seven elements; customer behaviour and demand forecasting, control system, revenue factors, variable cost factors, fare products, problem scale, and problem interfaces. In control system, one factor is the overbooking concept which is selling tickets over the capacity to increase capacity utilisation in case of no-show probability of ticketed passengers. However, risks are involved when implementing an overbooking strategy. The main risk is that it is unknown how many passengers will show up or not at the time of departure for the flight. If the number of passengers show up for the flight exceeds the capacity, the airline has to deny passengers and have to compensate the denied passengers which will incur as a cost, decreasing the profit. It has been noted that most of the previous works used estimation or random probability on deciding the number of go-show or no-show passengers. This is impractical as in most cases there is no defined/known probabilistic behaviour that could model most of the aspects of oversold tickets problems. The aim of this research is to solve overbooking problem in the airline industry to maximize revenue using mathematical models based on fuzzy optimisation. This will assist in deciding how many overbooks are optimal per single-leg flight.

3 - Recent Developments in Aircraft Recovery Problem: A Review of Cornerstone Models
Aykan Akincilar, *Ertan Güner*

Recovery models have gained a tremendous importance in airline planning since a possible disruption is almost inevitable even in the most sophisticated airline planning models. The airline recovery models are hard to deal with by the reason of their crucial challenges such as time, complexity, etc. In addition, these recovery models inherently have high interactions between the major sources of airline planning, e.g. aircraft, crew, and passenger. Aircraft recovery problem is the first step of recovery problems for most of disruptions in airline scheduling and, additionally, is the most studied one. In this study, a literature review of the cornerstone papers which contributed significantly in aircraft recovery problem were presented and the contributions of those innovative approaches were underlined. Then, after debating the status of the existing literature in airline recovery problem, future works were tried to be shaped according to the tendency of the literature. And finally, robustness in airline planning problem was discussed with the main lines as another very important aspect of airline planning. As a consequence, it was shown that OR has been playing since 90s, and can continue to play, an important role in aircraft recovery problem, more generally in airline planning problem.

4 - Routing of Aircraft
Johan Oppen

Large parts of Norway are sparsely populated, with long distances between small communities. In such areas the demand for air transportation is too small to make it possible for commercial airlines to make a profit. In order to provide an acceptable service level in terms of aviation routes, the Norwegian government buys services from one or more airlines to maintain a route network and offer air tickets at reasonable prices. This purchase of services is done based on a bidding competition where airlines are asked to give a tender for providing services according to a set of specifications.

In this work we have developed mathematical models and solution methods to describe and solve a routing problem associated with a set

of specifications for how a given network of airports should be served. Such specifications are typically given in terms of minimum number of seats and number of flights for the different connections, maximum travel times and flights to airports where connections to the main network can be done.

From a public point of view, there is a tradeoff between the service level provided and the price paid, and we show how our models and methods can be used to compare different alternatives.

■ TC-50

Tuesday, 12:30-14:00 - Graham Hills GH512, Level 5

Maritime Transportation 2

Stream: Maritime Transportation
Invited session
Chair: *Harilaos N. Psaraftis*

1 - Modeling Liner Shipping Service Selection and Container Flows using a Multi-layer Network
Christian Vad Karsten, Anant Balakrishnan

We introduce a new formulation for the tactical planning problem facing container shipping companies of selecting the best subset of sailing routes from a given pool of candidate routes so as to maximize profit. Since most containers are sent directly or transshipped at most twice in current liner shipping networks, we impose limits on the number of transshipments for each container (which most previous models do not incorporate). Our multi-layer multi-commodity model associates one commodity with each container origin port, and decides the route for each commodity on a logical network layer whose arcs represent segments (pairs of ports between which a container can use a single service). This approach, combined with commodity flow variables that are indexed by segment sequence permits us to incorporate the transshipment limits while also tracking the commodity's outflow from the system at various individual destinations. We model the service selection and capacity constraints at the physical layer by allocating the total flow on each segment to various chosen services that can transport the loads on the segment, subject to service capacity constraints. These modeling strategies yield a model that is smaller and easier to solve than a disaggregated multi-commodity model with transshipment limits. We present computational results for realistic problem instances from the benchmark suite Liner-Lib.

2 - Models for a Vessel Crew Scheduling Problem
Alexander Leggate, Robert van der Meer, Kerem Akartunali, Seda Sucu

Optimization techniques for the scheduling of employees have been widely studied in many areas of the transportation industry, including railway crew and most notably airline crew scheduling. The problem of crew scheduling in maritime transportation appears to be no less challenging to solve by other means, while the high proportion of expenditure on crew costs suggests an opportunity to use modelling tools to achieve cost savings. Despite this, the use of optimization tools in the industry appears scarce, and there are very few occurrences of maritime crew scheduling problems in the literature. Our research has focussed on the crew scheduling problem faced by a large maritime company conducting an Offshore Service Vessel type operation on a global scale, which by its nature requires an approach to be taken which is distinct from other maritime crew scheduling problems which have been studied. We discuss our experience of formulating the problem, which has seen the development of two mathematical models. The first is relatively simple to solve with standard techniques, but makes a number of simplifying assumptions; the second is much more realistic, but requires a more tailored solution approach. We will give an outline of our solution approaches, which have been designed to underpin the implementation of a decision support tool within the company's scheduling process.

3 - Speed Optimization in Liner Shipping Network Design
Berit Dangaard Brouer, Christian Vad Karsten, David Pisinger

In the Liner Shipping Network Design Problem (LSNDP) services sail at a given speed throughout a round trip. In reality most services operate with a speed differentiated head- and back-haul, or even individual

speeds on every sailing between two ports. The speed of a service is decisive for the bunker consumption in the network as well as the transit time of cargo. Speed optimization has been considered for tramp shipping showing significant reductions in fuel consumption. However, variable speeds has not been considered for post optimization of the LSNDP, where speed optimization could result in changes to the cargo flow due to transit time restrictions as well as significant savings in fuel consumption and required vessel deployment due to a weekly frequency requirement. We present a heuristic method to calculate variable speed on a service and present computational results for improving a solution of the LSNDP with average speeds to a solution with variable speed. We analyse the results according to transit time, fuel consumption and vessel deployment.

4 - Alternative solution methods for handling disruption in offshore supply logistics
Kjetil Fagerholt, Magnus Stålhane

Significant costs and reduced service quality are caused by disruptions to planned routes and schedules for offshore supply vessels supplying oil and gas installations on the Norwegian continental shelf. The disruptions are mainly due harsh weather conditions extending the sailing and handling times, unexpected orders, and uncertain order volumes. We formulate the problem as a version of the Pickup and Delivery Problem. The planning objective is to get back on plan within the next few days with as small negative consequences as possible, both regarding costs and service. The decisions that we consider are vessel rerouting, short-term chartering of an additional vessel from the spot market, and postponing order deliveries. The model is implemented in commercial optimization software and tested on several instances based on real data from the oil and gas company Statoil. Since the results show that a commercial solver is able to solve small instances of the problem only, we also propose and test both heuristic and exact solution methods, which are shown to provide practical decision support for the real problem.

■ TC-51

Tuesday, 12:30-14:00 - Graham Hills GH542, Level 5

MAI: Life beyond financial services: analytical lessons from manufacturing

Stream: Making An Impact 1 (MAI 1)
Invited session
Chair: *Gillian Groom*

1 - Life beyond financial services: analytical lessons from manufacturing
Gillian Groom

Manufacturing and finance are both sectors which make extensive use of data analytics and analytical tools. But the tools they use are different. There are big opportunities for finance and other service sectors to learn from manufacturing experience. This workshop looks at some specific tools and approaches used in manufacturing, and explores how financial or other service organisations could use these methods.

The workshop is particularly aimed at people working in service sector organisations who would like to broaden their repertoire of analytical tools, and review some of the technical, practical and cultural factors that emerge when applying standard tools in different sectors.

■ TC-52

Tuesday, 12:30-14:00 - Graham Hills GH554, Level 5

Commodities Modelling: Recent advances in the Emission Trading world

Stream: Financial and Commodities Modeling
Invited session
Chair: *Silvana Stefani*
Chair: *Rita D'Ecclesia*

1 - SPARK: Modelling the Joint Dynamics of Multi-Commodity Spot and Forward Prices
Olivier Daxhelet, Sébastien Chaumont, Johan Paduart

SPARK is an equilibrium model, developed in GDF SUEZ to simulate energy commodity prices and replicate statistical features observed on energy markets. We focus on the co-movement of commodity prices, which allows for a realistic modelling of the spreads between different commodities.

The mathematical framework is a multi-stage cascading sequence of stochastic processes, extending on the work by Geman-Borovkova. In particular, we use a low number of risk factors per market (improving stability). The key idea lies in its multi-stage modular structure: - The core module focuses on equilibrium relations that drive the joint dynamics of "average' forward prices across different markets. For each market and quotation date, we produce a single average price level, consistent with the price levels on other markets. - A second stage extends the latter to produce the full term-structure of forward curves, from month-ahead to up to three-year maturities. If needed, it also produces distinct peak-offpeak prices. - Finally, spot prices are derived from the short-end of forward curves. Spikes are modelled through a multi-commodity Markov chain. Hourly stochastic prices can also be obtained by bootstrapping techniques.

Resulting price paths replicate a set of inner-commodity indicators (seasonality, volatility term structure, auto-correlation) and cross-commodity stationarity properties (correlations and time-bounded spreads) thanks to the proposed equilibrium model.

2 - Energy Commodities Prices: New Challenges for Risk Managers
Rita D'Ecclesia

Changing global economic conditions are giving rise to exciting new opportunities – and challenges – in energy trading. International trading houses are, whether in oil, natural gas or other commodities, extending their reach and scope.The energy trading sector continues to rapidly transform as more and more trading houses move towards a more integrated business model. For several years in a row energy prices have seen high volatilities and more importantly changing relationships respect to what historically had been considered a well known pattern. Recent natural gas and oil price dynamics may not bring a stable operating environment for businesses where energy is concerned. Risk managemnt strategies and energy production plans are usually built based on forecasts based on past observed patterns or using scenario planning. In our opinion it is crucial to provide an accurate understanding of the volatility pattern for Natural gas prices and Crude oil prices and of the correlation existing between these major fossil fuels. In this paper we study the volatility of energy commodities and measure their interrelationship. Using daily prices for the north-european markets and the US markets over the period 2000-2014 we take account for structural breaks detected in each market and show how volatility patterns for natural gas and crude oil largely differ. A very important result is represented by the low and in some cases absent

■ TC-53

Tuesday, 12:30-14:00 - Graham Hills GH614, Level 6

Applications of Dynamical Models 2

Stream: Applications of Dynamical Models
Invited session
Chair: *Alberto Pinto*

1 - Price Dynamics in Hotelling Model.
Alberto Pinto, Jorge Soares

In 1929 Hotelling presented a model for spacial competition between firms in which they compete in two-stage game. First both firms choose their location and after they choose their price. In this work we assume that the establishement of prices hapens in a dynamic way instead of a static one. We will use a certain type of dynamics and our main goal will be to study the stability of the Nash Price Equilibrium. In particular we study the conditions that make the sef of prices with local market structure, that is every firm has a non-empty market share, a forward invariant set. Two cases will be studied, the Hotteling line model in terms of linear dependence on the transportation costs and the Hotteling line model in terms of quadratic dependence on the transportation costs.

2 - Uncertainty costs on an international duopoly with tariffs
Filipe Martins, Alberto Pinto

We consider two firms located in different countries selling the same homogeneous good in both coun- tries. In each country there is a tariff on imports of the good produced in the other country. We compute the Bayesian-Nash equilibrium and we analyse the effect of the production costs uncertainty on the profits of the firms and on the welfare of the governments. We show that the expected profit of the firms and the expected welfare of the governments increase with the variances of the production costs of both firms. When the production costs of the firms are similar, we show that this international trade model is like the Prisoner's Dilemma in the sense that the Bayesian-Nash equilibrium consists in both governments to impose tariffs but if both governments do not impose any tariff then both countries will have a higher welfare.

3 - Game Theoretic Approaches to Allocation Problems with Multiple Criteria for Evaluation
Jing Fu

This research deals with the problem of fairly allocating a certain amount of benefit among individuals or organizations when they are evaluated with multiple criteria for their performance. We first formulate the problem as a strategic form non-cooperative game and study the Nash equilibrium, the coalition-proof Nash equilibrium and the strong equilibrium. We show that the Nash equilibrium always exists, and make clear the condition that the coalition-proof Nash equilibrium coincides with the Nash equilibrium. The strong equilibrium may not exist.

Then based on the strategic form game, we construct a TU characteristic function form cooperative game. It is shown that the game is constant-sum and the core is non-empty if and only if the game is inessential, that is, the evaluation indices are identical for all the criteria for each player. This means that in most cases the core is empty.

We then give an NTU characteristic function form game, and study the alpha-core and the beta-core. We show that the alpha-core is always non-empty, but the beta-core is empty in most cases.

4 - Reallocating Reliability Targets within a Supply Chain using Dynamic Cooperative Game Theory
Aby Subin, Lesley Walls, John Quigley

When project contracts are made between organisations in a complex supply chains like that of the aerospace industry, reliability is an important criteria in the initial supplier contract.The agreements on reliability targets are made in the initial phase of the project when there is a lot of uncertainty about the system design details and possible failure modes. Contracts that induce cooperative behaviour by providing incentives for negotiating reliability targets without affecting the system reliability target tend to reduce the overall cost and duration of projects. A problem that needs to be addressed here is the durability of the contract made for trading reliability targets. Certain contract may fail to meet the conditions required to sustain a cooperative behaviour among the suppliers overtime.

Dynamic cooperative games open an efficient modelling approach for capturing the coalitional behaviour of individual organisations over time under uncertainty. Such a solution concepts would help in reducing the cost incurred by the suppliers for reliability improvement by sharing the information gathered by implementing reliability improvement activities,such that the system reliability target remains intact.

We are proposing a dynamic reallocation model that will retain the cooperative behaviour among suppliers overtime and explore the benefits offered by this allocation mechanism in reliability development of complex systems.

■ TC-54

Tuesday, 12:30-14:00 - Graham Hills GH617, Level 6

System Dynamics Session 3

Stream: System Dynamics Modeling and Simulation
Invited session
Chair: *Evgenia Ushakova*

1 - Print-to-Online Transformation: A System Dynamics View on News Media
Evgenia Ushakova

The reading of news articles is currently undergoing a transition from print to online media platforms. This print-to-online transformation undermines the financial stability of traditional news organizations that have until now relied on revenues from printed publications and have granted free access to their websites. The revenue earned from online advertising does not offset the revenue declines of the print business; hence, such organizations are seeking to fully or partially monetize their online content. This paper explores such monetization strategies using a newspaper-website model based on the system dynamics methodology. The work presents a general system dynamics model and uses a case study to test the model's behavior and to analyze online content strategies. The final simulation results support the proposed paywall-based business model and contribute to the determination of the optimal combination of content disclosure and pricing.

2 - A Systemic View on Debt and Currency Crises: Russia in 2015 vs 1998
Tatiana Boyarskaya

In 1998 Russia experienced simultaneous distress on public debt and currency markets. That led to a default on domestic short term public debt instruments and a freeze on payments for most of the international public obligations. In addition, the consequences for the domestic consumer market were drastic, due to sharp devaluation. The uncertainty and complexity of the situation required exceptionally careful and thoughtful decision-making in terms of budget and monetary policies. Nowadays, less than two decades since the default, declining oil prices and geopolitical factors constitute a similar threat to the economic stability of Russia. A system dynamics approach is applied to quantitatively assess the crisis of 1998 in Russia, and to analyze various fiscal and monetary policies of the government at that time. These are compared to historical evidence, and to see whether the default could have been avoided or its destructive effect mitigated. We also apply the model to the present day situation. Based on the simulation results we suggest an optimal economic policy for the government within the boundaries of the model.

3 - Commercial Risks at the Dawn of the Low Carbon Future
Bent Erik Bakken

Lowering energy consumption will be a key to avoid global overheating, yet global fossil energy use shows few signs of decline. This inconsistency between what science says is required for the world to remain habitable, and apparent policy disregard represents a key dilemma for players who are dependent on the energy sector. This article develops a system dynamics model that tracks global energy stocks- and flows as well as vessels, grids and pipelines that transport them. Tagging incomes to all energy source and transportation stocks and flows enables a case study of what constitutes the main commercial risks for an energy dependent consulting organization. It is shown that within plausible range of energy system parameter values, major risk consists in the implementation and effect of efficiency measures and corresponding energy intensity of the economy; if e.g. high global building standards for energy efficiency are mandated, total energy use might be cut much and fast. This might lead to major income shortages for our client. Conclusions are both substantive and methodological. Substantive conclusions are partly that the case of the single firm can be generalized to organizations — including nations- with similar energy dependence in their income streams. Methodological conclusions include that for this case, the three risk analysis methodologies of sensitivity tests, Monte Carlo simulations, and Deep Uncertainty yield very similar insights.

■ TC-55
Tuesday, 12:30-14:00 - Graham Hills GH626, Level 6

Operational Research in Financial Accounting

Stream: Operational Research in Financial and Management Accounting
Invited session
Chair: *Matthias Amen*

1 - Analysing the structure of IAS 36 requirements — quantitative implications for earnings management
Matthias Amen

According to IAS 36 an entity has to recognise an impairment if the sum of the discounted net cash inflows of an asset (or cash generating unit) is lower than the carrying amount. The accounting standard gives guidance for calculations but also explicitly or implicitly offers possibilities for earnings management in the short term and in the long term. This presentation will analyse some quantitative structures of IAS 36 requirements and opportunities, and will discuss possible objectives and their quantitative implications on the accounting figures.

2 - A Journalist's Influence in the Process of Disclosure of Financial Statements in Brazil
Gustavo Krüger, Elivelto Correa

The mandatory publication of the Financial Statements of Public Companies and Private and Public joint stock company by the print media, as has been happening in the current model does not reach its goal, which is to guarantee the full exercise of Social Control in Brazil. There is a failure point in the cognitive process, represented by the semantic mismatch between the source and the destination of the information. In this context, the present study aims to investigate the impact of the inclusion of journalists in the Financial Statements production process, aiming to increase the social control of public actions. Thus, a survey was administered to 42 Brazilian journalists from December 2014 to February 2015. The main results show that the respondents believe they can increase social control, through: (1) language improvement; (2) design improvement. Furthermore, it was observed that one of the factors to be overcome is the language leveling between who produces the information (accountant) and the journalist. Journalistic technicality, combined with the technological resources available in the area, have the power to decrease the communication gaps that exist between different groups of society. It is understood that the journalist can act as an "interpreter" democratizing information through transliteration of technical terms and making financial statements easier to be understood by society.

3 - The Effects of Corporate Social Responsibility on Earnings Surprises
Wen-Chuan Miao

The study examines the relation between corporate social responsibility (CSR) and corporate financial performance. We propose a dual fame and wealth achievement hypothesis and a distorted resource allocation hypothesis to test the impact of CSR engagement on short- and long-term corporate financial performance. In line with our first hypothesis, we find that, given negative unexpected earnings announcements, firms engaged in CSR have relatively better market performance and operation performance in the short term compared to firms that do not engage in CSR. In line with our second hypothesis, we find that CSR activities generate higher short-term marginal profitability and maintain a long-term profitability potential.

■ TC-60
Tuesday, 12:30-14:00 - Graham Hills GH813, Level 8

Routing Applications - MILP Based Approaches

Stream: Routing I - Models and Methods
Invited session
Chair: *Deniz Aksen*

1 - Routing and Fleet Deployment in Liner Shipping with Spot Voyages
Vinícius Armentano, Rodrigo Branchini

The routing, scheduling and fleet deployment is an important integrated planning problem faced by liner shipping companies which also lift load from the spot market. This problem involves the coordination of the assignment of ships to contractual and spot voyages, and the determination of ship routes and schedules in order to maximize profit. We propose a new model for representing voyages as nodes of a directed graph which is used to build a mixed integer programming formulation. Besides contractual and spot nodes, another type of node is introduced to represent a combination of a contractual voyage with one or more spot voyages. The approach is tested on a set of instances that are solved by the CPLEX solver.

2 - Formulations for the Vehicle Routing Problem with Precedence Constraints

Deniz Aksen, Temel Öncan, Mir Ehsan Hesam Sadati

We present a comparative computational analysis of several mixed-integer linear programming (MILP) formulations adapted to the vehicle routing problem with precedence constraints (VRPPC). We expand and adapt to the VRPPC the following formulations which were originally proposed for the traveling salesman problem: 1) Single Commodity Flow Formulation attributed to Gavish and Graves (1978). 2) Two-Commodity Flow Formulation attributed to Baldacci et al. (2004). 3) Formulation based on precedence relations with valid inequalities and 3-index or 2-index binary routing variables to eliminate precedence violations. To the best of our knowledge, VRPPC has not been studied rigorously in the routing literature yet. Likewise, test problems for VRPPC are not available either. To bridge this gap, we modify several asymmetric TSP instances with precedence constraints (PCATSP) from the TSPLIB, which were also tested in Sherali et al. (Computers & Operations Research, 2014). We investigate the lower and upper bounding performances and the CPU time efficiency of these alternative VRPPC formulations using state-of-the-art commercial MILP solvers embedded in the optimization suite GAMS. The parallel computing capabilities of these solvers are leveraged by appropriate options. Incorporated into the tested formulations, we also try a number of valid inequalities in our quest for the tightest bounds, best feasible solutions and least CPU times.

3 - Two-Echelon Capacitated Routing Problem with Electric Vehicles

Wanchen Jie, Jun Yang, Min Zhang

In this paper, we present a two-echelon capacitated electric vehicle routing problem which aims to determine the delivery strategy under the battery driving range limitations. The electric vehicles have different load capacities, battery driving ranges, power consumption rates and battery swapping costs in the two-level system. we propose an integer programming formulation and improve the adaptive large neighborhood search heuristic for the problem. Several destroy and repair operators of battery swap station and battery driving range are introduced to change the feasibility of the current solution and increase the traveling distance of electric vehicles. Compared with the MIP solver of CPLEX and several sets of instances from the literature, our algorithm explores the solution space more efficiently and outperforms existing solution methods.

4 - A multi-period dial-a-ride problem with driver consistency

Kris Braekers, Attila Kovacs

Dial-a-ride services are transportation services offered to individuals requesting transportation between specific origin and destination locations. These services arise in the context of demand responsive transportation and they differ from taxi services for the fact that users may be grouped together in a vehicle. Dial-A-Ride Problems (DARP) are concerned with the design of efficient vehicle routes for performing such dial-a-ride services, using a fleet of vehicles with limited capacity. In the past, these problems have mainly been studied as routing problems with a planning horizon of a single day. However, in many applications of dial-a-ride services, such as the transportation of elderly and disabled people, users may repeatedly have the same transportation requests over a longer period of time. Additionally, these regular users appreciate to be always serviced by the same (subset of) driver(s). Service providers may hence improve their service quality by considering driver consistency over a longer planning horizon. This work therefore extends the standard single-day dial-a-ride problem to a general multi-period dial-a-ride problem with driver consistency. A mathematical formulation for the problem is proposed. Small problem instances are solved to optimality using an adapted version of an existing branch-and-cut algorithm. To solve larger instances, a metaheuristic solution approach is proposed. Preliminary computational results will be discussed.

■ TC-61

Tuesday, 12:30-14:00 - Graham Hills GH816, Level 8

Shared Mobility Systems - I

Stream: Routing II - Emerging Applications
Invited session
Chair: *Maria Battarra*

1 - Rebalancing in Bike Sharing System: Mathematical Formulations and a Mathheuristic Approach

Baoxiang Li, Tom Van Woensel, Dmitry Krushinsky, Dmitry Krushinsky

This paper deals with a pickup and delivery problem motivated by bicycle sharing systems with demand ranges. In a bicycle sharing system, the stations are required to have an inventory of bicycles within given lower and upper bounds, based on historical user data. Some stations may have higher demand than others. If no action is taken, the inventory in these stations may rapidly reach a bound, thus preventing other passengers from picking up or dropping off bikes. A solution is to use vehicles to transport bikes from full stations to stations with shortages to balance the network. We formally define the problem and present a mathematical formulation. This formulation, however, is complex to get an exact solution. We propose a heuristic method to solve this problem, which includes three steps: (i) local search heuristic to get an upper bound, (ii) Lagrangean to get a lower bound, (iii) improve the final solution based on tabu search or branch and cut algorithm. The method provides a good lower bound in a reasonable time. We thus believe that our approach is suitable for practical implementation in bike sharing systems. The proposed heuristic can be applied to other vehicle routing problems, as well as to other sharing systems.

2 - Optimal Fleet Deployment Models with Stochastic Demand for Bike-Sharing Systems

Chung-Cheng Lu, Shangyao Yan

This research addresses the fleet deployment problem with stochastic demand for bike-sharing systems. The proposed models determine optimal assignment of bicycles to the stations of a bike-sharing system with the objectives of maximizing profit and minimizing unmet demand, respectively. We represent stochastic demand using a set of discrete scenarios with different probabilities. The models are then developed based on multiple time-space networks, each of which represents a given demand scenario for the system and effectively describes bike movements in the spatial and temporal dimensions. As a result, the models are formulated as integer multi-commodity network flow problems, which are NP-hard. While small-size instances of the problem can be solved using off-the-shelf software (e.g., CPLEX), this research develops a heuristic to efficiently obtain good quality solutions for large-size instances. Test instances are generated using real data from a bike-sharing system in Taiwan to evaluate the performance of the models and the algorithm. The test results show that the models can help the system operator of a bike-sharing system make effective fleet deployment decisions.

3 - A multi-type bicycle repositioning problem

Yan-Feng Li

This paper investigates a new static bicycle repositioning problem that considers multiple types of bicycles. Some types of bicycles with shortage can be substituted by others for usage at stations, while some types of bicycles can occupy the spaces of other types in the repositioning vehicle during the repositioning process. The problem is formulated as a mixed integer linear programming problem to minimize the total cost including total travel cost, penalty cost due to unmet demand, and penalty costs associated with substitution and occupancy strategies. A combined tabu search method is proposed to solve the problem. Tabu search is adopted for determining routing decisions while three methods, namely the exact method, the greedy and the mixed greedy method, are proposed to be embedded with the tabu search to determine the loading and unloading instructions, the substitution and the occupancy strategies. From the numerical examples, we reveal the special properties of this problem and the repositioning strategies with multiple types of bikes. The examples also illustrate that the performance of the proposed method, which is more efficient than directly solving the problem by the exact method. Among the three embedded methods, the exact method always obtains the best solution while the greedy heuristic can get good quality solutions within much shorter computation time, and the mixed greedy method can make a good tradeoff between the solution quality and the computation time.

4 - An exact algorithm for the Static Bicycle Rebalancing Problem

Maria Battarra, Gunes Erdogan, Roberto Wolfler-Calvo

Bicycle sharing systems can significantly reduce traffic, pollution, and the need for parking spaces in city centers. One of the keys to success for a bicycle sharing system is the efficiency of rebalancing operations, where the number of bicycles in each station has to be restored to its target value by a truck through pickup and delivery operations.

The Static Bicycle Rebalancing Problem aims to determine a minimum cost sequence of stations to be visited by a single vehicle as well as the amount of bicycles to be collected or delivered at each station. Multiple visits to a station are allowed, as well as using stations as temporary storage. This paper presents an exact algorithm for the problem and results of computational tests on benchmark instances from the literature. The computational experiments show that instances with up to 60 stations can be solved to optimality within two hours of computing time.

■ TC-62

Tuesday, 12:30-14:00 - Livingstone LT203, Level 2

Operations Research 7

Stream: Operations Research, other
Contributed session
Chair: *JongChen Chen*

1 - Analysis of the relationships between regional apple price and web search traffic: A VAR approach
Hyoshin Choi, So Young Sohn

Consumers are expected to pay the high price for Geographical Indication (GI) products due to their reputation. This study empirically investigates whether the consumers' interest measured by the web search traffic about GI product actually affects its price. We use the weekly apple price data and web search. Vector autoregressive (VAR) model is used to analyze the relationship with web search traffic and price of both GI and non-GI products. The experimental results show that the price changes of both kinds of apples influence the web search traffic. Consequently, consumers' interest about GI apple does not affect the price, but they are sensitive to price. Proper publicity strategy is necessary for effective GI policy.

2 - On the construction of an intelligent assistance system for shoulder and back rehabilitation from the data of electromyography and acceleration through various extension
JongChen Chen, YingLing ChenChuang

The elderly are often bothered by the pains caused by adhesive capsulitis of shoulder and muscle contusion of lower back/waist. The aim of this study is to develop an integrated shoulder and back/waist intelligent assistance system, based on different ways of hand and back movements made by each individual. The information collected includes the dynamic muscle strength gathered from various rehabilitation exercises through accelerometers and electromyography modules. Using a previously-developed self-organizing system, our ultimate goal is to realize the design of a customized intelligent system for different people, times, and places, based on their individual needs, in assisting different needs of "back' and "shoulder' problem users. For the data collected, we first perform data prototype analysis and then transform the data into frequency, amplitude, and phasing using Fast Fourier Transformation (FFT). Through an artificial neuromolecular system constructed in our lab earlier, the data through FFT were used to differentiate behavior modes of different users. From the data of different rehabilitation motions, our aim is to find out the common behavioral characteristics from the same rehabilitation exercises on the one hand and to differentiate their differences so as to separate abnormal from normal people. Finally, our aim is to differentiate people activities under different situations.

3 - On Routing Multi-Commodity Flows in a Network with Diversified Paths and Concave Costs
Pablo Cortés, Luis Onieva, Jesús Muñuzuri, José Guadix

A high number of situations in transport and logistics deal with different commodities flowing in the same link. The optimal routing of such flows depends on the demand in the nodes and the existence of capacity constraints. Here, we consider capacity constraints as a diversification condition for each path connecting an origin-destination pair. Moreover, we consider an additional variant of the traditional problem by considering a concave cost function stating a non-linear objective function. This type of situation is quite common in certain situations of economies of scale. This problem can be adequately represented by the multi-commodity flow distribution in networks with diversification constraints and concave costs (MFDCC) problem. We present an iterative algorithm based on the Kuhn-Tucker optimality conditions of the problem that provides optimal distribution routes in such complex networks. The algorithm identifies three types of paths (or routes): a set of paths transporting all the demand allowed by its diversification constraint (saturated paths), a set of empty paths, and an indicator path transporting the remaining demand to satisfy the demand equation. Then, Kuhn-Tucker conditions are evaluated. In case of non-optimality, the algorithm reduces the total cost in the network and follows a monotonic sequence to the optimum. The algorithm is tested in a trial library reaching the optimum for all the instances.

4 - Solar photovoltaic development in Australia: A life cycle sustainability assessment study
Man Yu, Anthony Halog

Australia possesses the highest average solar radiation of any continent in the world, but solar energy in total contributes less than 1% to Australia's primary energy consumption. This study intends to assess whether solar photovoltaic (PV) is really a sustainable option for Australia's energy transition on the project level. An UNEP life cycle sustainability assessment (LCSA) was conducted on a 1.2MW flat-roof mounted PV solar array called UQ Solar, and the results suggested UQ Solar performed well in environmental aspects, except for emissions of several criteria air pollutants. It was economically feasible with the grant provided by Queensland Government, and the Levelized Cost Of Electricity (LCOE) was more or less the same as the LCOE of offset electricity. Its performance in social aspects was not as good as expected. Large-scale PV installations can be sustainable in Australia if several environmental, economic and social problems are addressed. PV manufacturers should be more responsible for reducing the use of hazardous materials; End-of-life treatment should be taken good care of; Government should truly support the deployment of large-scale PV installation by providing more incentives and infrastructures; Substantial subsidies for fossil fuel power stations should phase out; More awareness and training activities should be organised to promote the social acceptance.

■ TC-66

Tuesday, 12:30-14:00 - Livingstone LT209, Level 2

Routing 2

Stream: Optimization
Invited session
Chair: *Maria Gabriela Furtado*

1 - Bus transit network design with limited stop services
David Z.W. Wang

To enhance the financial sustainability of bus operations, many bus operators are offering differential service types, such as local and limited stop services. While the local service serves all the bus stops present on a network, limited stop service serves only a selected set of bus stops, which reduces the travel time to cater for the travel demands in favour of improved service quality. Therefore, it is imperative for bus operators to understand the optimal bus operations so that certain objective could be achieved. Basically, they need to address the problems of the optimal line settings of the limited stop services, i.e., which set of bus stops should be serviced; optimal bus allocation of existing bus fleet for the differential services, local bus services versus limited stop services; optimal service frequencies, etc. This study would present a mathematical programming approach to model and solve this transit network design problem. The model formulation can be regarded as a bi-level program, wherein the first level problem optimises the limited stop service network design, and the lower level describes passengers' bus services choice behaviour. Global optimization methods would be designed to solve the formulated mixed integer nonlinear programming to their global optimal solutions. In designing the global optimization solution method, various linearization and convexification techniques are applied. Numerical examples are then conducted to show the model validity.

2 - A mathematical model to find the optimal path in an multimodal urban transportation network
Ricardo Coelho Silva, André Shiguemoto, Manoel Campelo

In this study a metaheuristic and a mathematical model are proposed for finding the optimal path in an multimodal urban transportation network where public and private transport, such as bus, subway, taxi and walking routes are allowed. The problem is defined on a complete graph G = (W, E), where W is the set of nodes and E is the set of edges. During 12 hours of planning horizon for all buses and subways are set up timetables to departures and arrival or, or time windows associated at each stop point. For a pre-defined set of bus routes and subways, with their respective stop points and timetables, once defined starting and ending points, with respective times, the goal is to find a way that minimizes the distance traveled and the time sum, using different transport modes subject to the following constraints: a) bicycles can only be removed and returned at the point of hire; b) the moment of arrival at a point cannot occur before the time of arrival in the previous point; c) boarding and landing in a bus or subway, only are allowed on the stop points; d) If the arrival at the stop point to take after the moment of departure, the person must wait until the next moment of departure. The proposed metaheuristic will be tested on a real network and academic instances generated through GIS maps.

3 - A Constraint Programming Approach for the Time-Dependent Traveling Salesman Problem with Time-Windows

Penelope Aguiar Melgarejo, Philippe Laborie, Christine Solnon

When we consider real world optimization problems, time is usually an important dimension to take into account. This is particularly the case for Delivery Problems for which time is typically present in the form of travel times between deliveries, authorized delivery time windows or precedence constraints. We are interested in the Time-Dependent Traveling Salesman Problem (TDTSP), an extended version of the TSP where the travel time between deliveries depends on the date of the travel. The TDTSP is at the core of many real-world scheduling problems such as urban delivery problems, for example, since traffic conditions in urban areas usually vary a lot during the day. The TDTSP has not been much studied in the literature and Constraint Programming (CP) approaches are even rarer. One reason for this is that CP is usually less efficient than other methods for time-dependent vehicle routing problems. On the other hand, Constraint-Based Scheduling, that is the application of CP to scheduling problems, is one of the biggest industrial success of CP and has shown that CP technologies can be very efficient for solving temporal problems. We introduced a new benchmark for this problem generated from real-world traffic data. Using CP techniques, we propose a new global constraint for efficiently handling time-dependent travel times and show experimentally that the resulting model outperforms a classical CP one on our realistic benchmark.

4 - Pickup and Delivery Problem with Time Windows: A 2-Index Formulation with a Polynomial Number of Constraints

Maria Gabriela Furtado, Pedro Munari, Reinaldo Morabito

In the pickup and delivery problem with time windows a set of vehicles with limited capacity has to satisfy the customer requests, satisfying precedence relations. There are two main types of models: 3-index and 2-index formulations. The models with 3-index variables represent compact formulations that can be easily solved by a black box optimization software and have a polynomial number of constraints with respect to the number of requests. The models 2-index have less variables, but require an exponential number of constraints, then have to be solved by a branch-and-cut method. We propose a new 2-index formulation for the pickup and delivery problem with time windows in which the number of constraints is polynomial on the number of requests. The new model combines the advantages of 3-index models (compact formulation with a polynomial number of constraints) with those of 2-index models (reduced number of variables). The computational experiments performed with instances available in the literature indicate that the proposed model has a good performance compared with the 3-index formulation.

■ TC-67

Tuesday, 12:30-14:00 - Livingstone LT210, Level 2

Applications of Discrete Optimization

Stream: Combinatorial Optimization
Invited session
Chair: *Dorit Hochbaum*

1 - ILP Formulations for the Lazy Bureaucrat Problem

Ivana Ljubic, Fabio Furini, Markus Sinnl

Lazy reformulations of classical combinatorial optimization problems are new and challenging classes of problems. In this paper we focus on the Lazy Bureaucrat Problem (LBP) which is the lazy counterpart of the knapsack problem. Given a set of tasks with a common arrival time and deadline, the goal of a lazy bureaucrat is to schedule a least profitable subset of tasks, while having an excuse that no other tasks can be scheduled without exceeding the deadline.

Three ILP formulations and their CP counterparts are studied and implemented. In addition, a dynamic programming algorithm that runs is pseudo-polynomial time and polynomial greedy heuristics are implemented and computationally compared with ILP/CP approaches. For the computational study, a large set of knapsack-type instances with various characteristics is used to examine the applicability and strength of the proposed approaches.

2 - Combinatorial Algorithms for Effective Machine Learning and Clustering in Image Segmentation and data mining

Dorit Hochbaum

We present models for clustering and binary classification which combine two criteria. One of the models, called normalized cut prime" (NC'), is to find, for a given a collection of objects with pairwise similarities, a cluster that is as dissimilar as possible from the complement, while having as much similarity as possible within the cluster. The combined ratio problem is shown to be solved by a combinatorial algorithm within the complexity of a single minimum s,t-cut algorithm. This problem is a relaxation of the NP-hard normalized cut problem. We generalize the problem to "q-normalized cut" which includes a form of minimizing the Rayleigh ratio on discrete variables which is shown here to be polynomial time solvable. This is significant since major problems in clustering, partitioning and imaging can be presented as the Rayleigh ratio minimization on discrete variables and an orthogonality constraint. We compare a continuous and discrete relaxations of the Rayleigh ratio, where the first is the spectral method and the second is the combinatorial algorithm. We demonstrate a number of advantages for the combinatorial algorithm including a better approximation, in practice, of the normalized cut objective and better practical results. We show that NC', is an effective machine learning method that often performs better than leading techniques for data mining.

3 - A Dynamic Programming Approach for the Maximum Cycle Packing Problem

Peter Recht

Let G= (V,E) be an undirected graph. The maximum cycle packing problem is to find a collection C = C_1, C_2, ..., C_s of edge-disjoint cycles C_i in G such that the cardinality s of the collection is maximum. In general, this problem is NP-hard. It is proved that if a collection C of edge-disjoint cycles satisfy the condition that -among all such collections- it is a minimizer of the total sum of the square length of all its cycles, then C is a maximum cycle packing. This result leads to a dynamic programming approach for getting "min-max" cycle packings of G. An A* shortest-path procedure on an appropriate network N is presented to solve this problem. Within this procedure a special monotonous node potential heuristic is used.

■ TC-69

Tuesday, 12:30-14:00 - Livingstone LT212, Level 2

Computational Statistics and Stochastic Dynamics

Stream: Computational Statistics
Invited session
Chair: *Gerhard-Wilhelm Weber*
Chair: *Pakize Taylan*

1 - PCF Based Preprocessing for Linear SVM
Emre Çimen, Gurkan Ozturk

In machine learning and statistics, classification is one of the important problems and Support Vector Machines (SVM) based algorithms generate successful classifiers for this problem. But, generally, the very basic version of it, Linear SVM, cannot be used without kernel functions. Because of the fact that kernel functions play a key role for SVM based classifiers' robustness and accuracy, the decision of the type and the parameters of the kernel function is a problem. With this study, it is aimed to remove the need for kernel functions, and also their decision problems. Polyhedral Conic Functions are generated in a preprocessing step and these function values are used for training a Linear SVM. Some famous dataset test results are provided.

2 - Student Success Prediction for the Mega University of Turkey
Gurhan Ceylan, Gurkan Ozturk, Zehra Kamisli Ozturk, Sinan Aydın

Anadolu University, third mega university of the world and has approximately two millions of students and more than two millions of graduates. In general, the open and distance education system has terabytes of data related to the students and graduates. These data have been serving to make strategic and operational decisions such as on location, on the numbers and capacities of the offices, and on the number of the books to be printed. On the other side, these huge data have potentially useful patterns which can be used to improve overall education quality. In this study, we propose a system to find such patterns related with the success of the students. Each of these classifiers is trained with different datasets with hundred of thousands of rows with respect to departments. The obtained classifiers will serve as a recommendation system for students who want to select courses before the semester registration.

■ TC-70

Tuesday, 12:30-14:00 - Livingstone LT303, Level 3

Geometric Clustering

Stream: Geometric Clustering
Invited session
Chair: *Peter Gritzmann*

1 - Generalized power diagrams, balanced k-means, and the representation of polycrystals
Peter Gritzmann

Based on a discrete convex maximization model we give an efficient algorithm for computing feasible generalized power diagams with near-optimal separation properties. Further, we show how this approach can be used to generalize the classical k-means algorithms from data analysis so that it becomes capable of handling weighted point sets and prescribed lower and upper bounds on the cluster sizes. (This part is joint work with S. Borgwardt and A. Brieden).

Also we indicate how to handle the discrete inverse problem from material science to compute grain maps i.e., representations of polycrystals, based only on measured data on the volume, center and, possibly, moments of their grains. (This part is joined work with A. Alpers, A. Brieden, A. Lyckegaard and H. Poulsen)

2 - Generalized Power Diagram Inversion
Andreas Alpers, Andreas Brieden, Peter Gritzmann

The generalized power diagram (GPDs) of a given set of sites and distance functions (defined by a certain set of parameters) divides the n-dimensional space into cells such that, for all points in a cell, the distance to the site within that cell is not larger than the distance to all other sites. GPDs generalize, amongst others, the concept of Voronoi diagrams. Recent applications are in the field of microstructural modeling of polycrystalline materials.

The problem of GPD inversion — that is, recovering the sites and parameters of the distance functions — has been studied in special cases, for instance, for Voronoi diagrams. Based on linear programming duality, I will provide in this talk an approach that unifies and generalizes results from the literature. Computational aspects are also discussed.

This is joint work with Andreas Brieden and Peter Gritzmann.

3 - Electoral district design using power diagrams and generalizations
Fabian Klemm, Peter Gritzmann, Andreas Brieden

Electoral districts in a representative democracy need to be constantly adapted due to census developments. By law, districts need to be equally-populated and geographically connected. We model this as a geometric clustering problem under balancing constraints.

We transfer and adapt methods that have been successfully developed and applied in the field of farmland consolidation. Additively weighted Voronoi Diagrams - called Power Diagrams - are well-known to yield least square assignments under balancing constraints. By LP duality there is a one-to-one correspondence between extremal points of a certain polytope and power diagrams. While clustering under balancing constraints is NP-hard, the LP relaxation yields reasonable bounds for the maximum violation of balancing constraints after rounding.

Further generalizations of Voronoi Diagrams are discussed: District-dependent anisotropic metrics can be used to avoid massive changes in the district design and account for possible non-convex shapes of states. Also, geodesic distances can be incorporated via considering shortest paths in a graph of neighboring municipals.

This is joint work with Andreas Brieden and Peter Gritzmann.

■ TC-71

Tuesday, 12:30-14:00 - Livingstone LT307, Level 3

Network design

Stream: Telecommunications and Network Optimization
Invited session
Chair: *Bernard Fortz*

1 - Feasible solutions for the Minimum-Weighted Tree Reconstruction Problem
Cristina Requejo, Bernard Fortz, Olga Oliveira

The Minimum Weighted Tree Reconstruction (MWTR) Problem is such that by knowing only pairwise distances between a set of terminal nodes we seek to reconstruct its underlying connection tree and associate weights to the edges such that the total edge weight is minimized. This problem has applications in several areas, namely, the inference of phylogenetic trees, the modeling of traffic networks and the analysis of internet infrastructures. We present mixed-integer linear programming models for the MWTR problem that are used to obtain solutions to the MWTR. The corresponding LP solutions together with heuristic techniques, such as the Feasibility Pump used to accelerate the finding of an initial feasible solution and the Local Branching used to explore the feasible region and improve a feasible solution, are used to accelerate the finding of feasible solutions. Extensive computational results show that the process is quite effective in finding integer feasible solutions, present small gap values, and solve high sized instances.

2 - Design of survivable networks with length constraints
Markus Leitner, Luís Gouveia, Ivana Ljubic

We consider the k-edge Survivable Hop Constrained Network Design Problem (k-HCNDP). Given is an undirected graph, with nonnegative edge costs, a set of commodities, two hop limits for each commodity pair, and a parameter k specifying the required redundancy. Feasible solutions of the k-HCNDP are subgraphs containing a path of length at most H for each commodity pair and a path of length at most H' between its nodes after removing at most k edges. We first observe that solving this problem is not equivalent to designing a network containing a number of disjoint paths of length at most H and H', respectively, between each relevant node pair (the hop-constrained survivable network design problem (HSNDP) for which different integer programming formulations and solution algorithms have been proposed for the case H = H'). The reason for this is that Mengerian-like theorems do not hold for paths with hop constraints, i.e., designing a network including k edge disjoint paths with at most H hops between two nodes is not equivalent to designing a network guaranteeing the existence of a path with at most H hops between them after the failure of k-1 edges. Besides showing that the solutions to the problem can be different from the ones of the HSNDP, we propose integer programming formulations for the case of a single failure (i.e., for k=1), and analyze whether the solutions are really different from those obtained from considering the classical HSNDP.

3 - Computational strategies for a multi-period network design and routing problem
Bernard Fortz, Enrico Gorgone, Dimitri Papadimitriou

The multicommodity capacitated network design problem deals with the simultaneous optimization of capacity installation and traffic flow routing, where a fixed cost is incurred for opening a link and a linear routing cost is paid for sending traffic flow over a link. We generalize this problem over multiple time periods using an increasing convex cost function which takes into account congestion (number of routing paths per edge) and delay (routing path length).

We propose a compact Mixed Integer Linear Program (MILP) formulation for this problem, based on the aggregation of traffic flows by destination. We observe that the resolution with realistic topologies and traffic demands becomes rapidly intractable due to the weak linear programming bound. We also introduce an extended formulation where traffic flows are disaggregated by source-destination pairs, while keeping the requirement of destination-based routing decisions. This extended formulation provides for all evaluated topologies stronger linear programming lower bounds than the base formulation. However, this formulation still suffers from the large size of the resulting variables and constraints sets; hence, solving the linear relaxation of the problem becomes intractable when the network size increases.

In this talk, we investigate different computational strategies to overcome the computational limits of the formulations. We propose different branch-and-cut strategies and a Lagrangian relaxation approach.

4 - On Acyclic Multi-state Transmission Networks with Vulnerable Nodes
Sanjay Chaudhary

Survivability, the ability of a system to tolerate intentional attacks or errors. The system is affected by hostile environment. A survivable system is useful under hostile situation if it completes its mission within time. The influence of availability of system is also a key point for entire system survivability. Survivability can be raised if system states are multi-state rather then binary. An acyclic multi-state transmission networks (AMTNs) with vulnerable nodes (positions) using the universal generating function (UGF) techniques is studied. The AMTN survivability is defined as the probability that a signal from root node is transmitted each leaf node. The AMTNs consist of a number of positions in which multi-state elements (MEs) capable of receiving and /or sending a signal are allocated. The MEs located at each non-leaf positions. The two MEs located at first position. The number of MEs is not equal to the number of non-leaf positions. The AMTNs survivability is defined as the comparison of two networks. All the MEs in the network are assumed to be statistically independent. The signal transmission is possible only along links between the nodes. The networks are arranged in such a way that no signal leaving a node can return to this node through any sequence of nodes.

■ TC-73
Tuesday, 12:30-14:00 - Collins CL205, Level 2

Business Forecasting

Stream: Forecasting & Time Series Prediction
Invited session
Chair: *Jan van Dalen*

1 - Optimising statistical forecasting models in real time with Bayesian component using 'big data' in marketing
Ivelis Montilla, Maria Antonieta Di Alessio, Antonio Boada

This article intends to emphasize the relevance of the generation of a solid structure for historical register (hard data derive from billing and logistics areas) and subjective information handling (marketing strategies) that allows a company registering and enquiring about some information on real time. Hence, it would be possible to simulate, forecast and update future demands, in an efficient way, in corporately determined time period. The use and handling of huge amount of digital information, following well structured business specifications, would generate a solid structure of Big Data that would be able to create robust data matrices on real time which would allow updating simulation systems according to the tendency of the products demand along

the time. Techniques, such as Bayesian Dynamic Models, can be updated in real time through Dynamic Tables with Bayesian adjustment of arithmetic average on the demand with softening logarithm. This model would produce stimulating as well as inhibiting indicators that function as "input' for Multivariate Statistical Forecasting Models.

2 - Scaling-up forecasting algorithms for industry applications
Yang Li

Forecasting is a key business function in every company; it becomes increasingly sophisticated for large utility business operations where hundreds of business drivers (e.g. programmes), be it new provide, routine maintenance, or fault fixing, compete for shared pool of resources that contains tens of thousands of workers spreading across hundreds of patch areas in the country. Existing forecasting algorithms, be it statistical-based or machine-learning-based, mainly look at one or few business drivers for a small number of chosen areas, and primary concerns are given to forecasting accuracy of these algorithms. Typically, they are implemented using procedural languages such as Java, Javascript or R, which, when being scaled up to all the business drivers and areas, often crash computer server memory and make themselves unable. To tackle this problem, we introduced a new relational approach that can simultaneously handle forecasting for a large combination of business drivers and areas in one session. In this talk, I would like to share this approach and also how it was used to deal with tactical forecasting and strategic forecasting in live operational deployments.

3 - Product Dependencies and Hierarchical Forecasting
Clint Pennings, Jan van Dalen

Forecasts are often made at various levels of aggregations, where items at lower levels of the hierarchy are combined into groups at the next level. In a manufacturing company, forecasts for products, product types, and product groups resemble such a hierarchy, yet this is not always taken into account when the forecasts are made in practice, which means that issues such as product substitution and cannibalization are ignored. Various hierarchical approaches, of which some quite recent, have been proposed in the literature, but differ to the extent to which they can incorporate this. We present a review of hierarchical approaches outlined in forecasting literature and compare and contrast them based on simulated data and on two empirical data sets of sales of fast moving consumer goods. We specifically examine possible correlation and dependencies at various layers of the hierarchy and its consequences. We show when performance falls and propose remedies for these cases so that consistent forecasts can be made.

■ TC-77
Tuesday, 12:30-14:00 - Collins Insight Institute

Behavioural issues in negotiation theory and support

Stream: Behavioural Operational Research
Invited session
Chair: *Rudolf Vetschera*

1 - The impact of preference visualization and the negotiators' profiles on scoring system accuracy
Tomasz Wachowicz, Gregory Kersten, Ewa Roszkowska

The scoring systems, which use a multiple criteria decision making algorithm, are the decision support tools employed for the purpose of comparison and evaluation of the negotiation offers. They are also used to analyse the degree of concessions made by the negotiators. In this paper we analyse how such scoring systems are constructed by the negotiators in software-supported negotiations when Simple Additive Weighting (SAW) method is used to elicit their preferences. We analyse a dataset of the Inspire e-negotiation system, containing the transcripts of bilateral negotiation experiments. We focus on the way the negotiators use the preferential information provided in a discrete negotiation case and map it into a system of issues and options ratings. The accuracy of the preference elicitation and score construction is measured using the comparison of the user-defined scoring systems and the reference one derived from the graphical and verbal information that is included in the case. An assessment of the accuracy of the scoring system is given. The potential accuracy determinants are:

(1) the negotiators' profile, described by both their conflict mode and thinking style; and (2) the preference visualization technique used to present the preferential information to the Inspire system users. The impact of inaccurate scoring systems on the negotiation outcomes is also discussed.

2 - The influence of different support approaches on negotiation processes and outcomes
Michael Filzmoser, Rudolf Vetschera

Negotiation support systems follow and implement various approaches to aid negotiators. Empirical studies of the performance of negotiation support systems, however, predominantly consider just one support approach and dimensions of the negotiation outcome which are especially relevant for that support approach. Decision support focuses on efficiency and the economic value realized in an agreement, behavioral support on the other hand, often aims at effectiveness and thus the prospects of reaching an agreement. Differences in support systems, negotiation problems and cases as well as experiment participants impede the comparison of different negotiation support approaches across studies. This paper compares decision support and behavioral support implemented as functionalities of one support system and evaluated in one experiment. Analyses not only consider various outcome dimensions of the negotiation process — i.e. agreement as well as efficiency and fairness of agreements reached — but furthermore closely investigate the negotiation process. We unravel the black-box of the negotiation process by standardized interpolated path analysis, which uncovers how negotiation processes over time lead to the negotiation outcomes observed. Our results indicate a clear relationship between process characteristics and outcome dimensions, but found no significant differences between decision and behavioral support on processes and outcomes.

3 - Securing e-negotiation deals
Mareike Schoop, Dominik Schoop

Electronic negotiations can be conducted via negotiation support systems (NSSs) that offer support of dislocated and asynchronous communication, decision making, document management, and conflict management. Whilst prior research has been conducted on different support functionalities and their effect on negotiation process and outcome, it has always been assumed that the NSS acts as a trusted third party (TTP) and is thus secure. However, revealing information to a system as well as to a negotiation partner raises the issue of trust. Whereas trust has been researched from a technical perspective and from a negotiation perspective, these two perspectives have usually not been combined. We will report on an experiment to research the interrelation between security awareness and information revelation during an electronic negotiation process. To this end, we conducted an experiment using the NSS Negoisst and two groups of students of the same university course. The first group was briefed on basic security issues such as the security values (i.e. confidentiality, integrity, authenticity, non-repudiation, and availability) and security risks whereas the other group did not received the briefing. We then analysed the negotiation behaviour of both groups w.r.t. the information they shared with the other party to find out whether the knowledge about potential security risks leads to less information sharing for fear of being exploited.

■ TC-78
Tuesday, 12:30-14:00 - Architecture AR201, Level 2

Soft OR/PSM applications I

Stream: Soft OR and Problem Structuring Methods (contributed)
Contributed session
Chair: *Alberto Paucar-Caceres*

1 - A case study in the application of SSM in student services within a major UK university
Bruce Levitan, Alberto Paucar-Caceres

Peter Checkland's Soft Systems Methodology (SSM) has a long and good record of development and application in Soft Operational Research and is one of the best established Problem Structuring Methods. It also has the advantage of offering a set of tools that can be used and adapted in varying business contexts. Whilst there are many good examples of the practical use of SSM, there are fewer in the HE environment, and solid case studies add to the corpus of evidence for the efficacy of SSM. This paper will demonstrate how aspects of SSM were used in a large university to help define the requirements for a new IT system to support the processing of students' mitigating circumstances. The case study will use some of the SSM steps such as CATWOE and root definition to understand the variation in current practice and why that is occurring, and to create a consensus view of what was needed. It will also demonstrate how the development of a consensus business activity model (BAM) was used as the conceptual model upon which a detailed user specification of the required system could be based.

2 - Criteria Identification for evaluating potential improvements in energy efficiency.
Jorge Augusto Pessatto Mondadori, Juliana Bezerra, Marcio Basotti, Daniel Corteletti, Mischel Carmen N. Belderrain

This paper uses problem structuring methods to identify criteria to evaluate the potential improvement in energy efficiency in industries. The studied region covers 13 cities in the metropolitan area of the South Ridge in the province of Rio Grande do Sul, Brazil. The largest city in this scope is Caxias do Sul, which has more than six thousand industries, mostly small and medium size ones, and without knowledge of energy efficiency concepts in depth. One of the main objectives of SENAI (National Service for Industrial Apprenticeship) Institute of Technology in Mechatronics of Caxias do Sul is to work along the industries in the region in order to increase the energy efficiency. The identified stakeholders are the industries, SENAI and governmental organizations. Using the VFB method of Keeney, and exposing the listed alternatives in a cognitive map seven clusters were identified that refer to low energy efficiency. Thus by combining this map with the actions of the Institute allowed elaborating a hierarchical model based on VFT of Keeney. Through this model, it was also obtained the hierarchical structure that represents the criteria identified by the authors and industrial community as important for achieving better energy efficiency.

3 - Using Autopoiesis to complement Checkland's SSM
Alberto Paucar-Caceres

The work of Maturana and Varela on the nature of living, the biological nature of cognition and knowledge have been having a far reaching influence on the systems and various others fields. It has been argued that Maturana's ideas lean more to a constructivist paradigm . We argue that SSM popularity and shortcoming seems to be a consequence of the interpretivism position, and we proposed to address this by bringing concepts developed from the constructivism paradigm in systems sciences. This paper attempts to address SSM limitations and attempts to enhance the above SSM applications, by exploring how two key concepts from Maturana's theory of Autopoiesis and Biology of Cognition (BoC) namely: (i) Structured-Determined Systems; and (ii) Organizational Closure might help to overcome the limitations and complement Checkland's SSM process. The propose a "modified' SSM framework in which the above concepts are grafted in SSM phases.

■ TC-79
Tuesday, 12:30-14:00 - Architecture AR310, Level 3

Sports Scheduling

Stream: OR in Sports
Invited session
Chair: *Stephan Westphal*

1 - The Stable Tournament Problem: matching sports schedules with preferences
Mario Guajardo, Kurt Jörnsten

While mathematical programming and other approaches have allowed to improve the way sports competitions are scheduled, it is not rarely seen that team representatives, players or fans complain about the schedules. Would each team state its own preferred schedule, could we find a schedule matching with their preferences? This motivates us to formulate the Stable Tournament Problem (STP). Its simplest version is in a compact single round robin tournament, where all teams play against each other once and all teams play one game per round. Suppose each team expresses its own preferred schedule, that is, the round in which it would like to play against each of the other teams. If

team A appears before team B in the preferred schedule of team C, it means that team C prefers to play earlier against A than against B. A schedule is stable with respect to the preferences of the teams if there are no teams who would prefer to play against each other in an earlier round. The STP consists of finding a stable schedule as similar as possible to the preferred schedules of the teams. We present a stable matching formulation for this problem and study several types of preferences and tournament sizes. We present results on whether stable schedules exist or not for these preferences and tournament sizes.

2 - The impact of Mathematical Programming in the Ecuadorian football league
Diego Recalde, Ramiro Torres, Polo Vaca Arellano

A sports schedule sets the dates and venues of games among teams in a sports league and it can be a highly restrictive problem. In this work, an integer programming (IP) approach for scheduling the Ecuadorian professional football league, considering the particular regulations of the league, together with equity and attractiveness constraints is proposed. This approach met the expectations of the Ecuadorian football federation (FEF) managers and since 2012 up to the present time, the authors have provided the schedules for each one of the editions of the professional football league in Ecuador. After the last successful work, FEF authorities posed a second problem concerning to the second division of the Ecuadorian football league: a set of n provinces must be grouped according to some constraints (geographical proximity, football teams' homogeneity) in k geographic zones where a double round robin tournament is played among the teams belonging to the provincial associations in each zone. The latter was modelled as a constrained clique partitioning problem and solved by IP techniques. The methodology was used as a decision tool to design the 2014 edition of the zonal league in the second division. We will describe our experience on these projects and the impact that they had on the Ecuadorian football league.

3 - Mathematical Models for an NBA-type Scheduling Format in the Argentina's National Basketball League
Guillermo Durán, Javier Marenco, Pablo A. Rey, Santiago Duran, Federico Mascialino

Argentina's first division National Basketball League has traditionally scheduled games only on weekends according to a coupled format. For the 2014-2015 season, however, the League adopted an NBA-type format proposed and modelled by the authors. In this setup, games are played any day of the week and away matches are scheduled in consecutive sequences of 2, 3 or 4 based on initial ad hoc team proposals for reducing travel distances. The problem to be solved is thus a variation on the well-known Travelling Tournament Problem.

The League currently has 18 teams split into 2 conferences (North and South) of 9 teams each. The first stage of the season is a conference-level double round robin and the second stage is a national double round robin. This is followed by playoffs to decide the season champion.

In this talk we present the models we used to define the League's schedules. The overall modelling approach is a two-stage process in which a first model specifies the order of each team's games and a second model then assigns dates to each match while satisfying a series of constraints requested by the teams and the Argentinean Basketball Clubs Association.

The application of these models has resulted in significant cuts in each team's total travel distance, with consequent reductions in operating costs and player fatigue.

A similar implementation was used to schedule the 2014-2015 season of the Association's national 24-team Second Division.

4 - A combined approach for approximating the Traveling Tournament Problem and the Traveling Umpire Problem
Stephan Westphal, Marco Bender

We consider a combined approach for approximating the Traveling Tournament Problem (TTP) and the Traveling Umpire Problem (TUP). In the TTP, the task is to construct a double round-robin schedule where no two teams play against each other in two consecutive rounds. There is an upper bound on the number of successive home or away games, and the task is to minimize the total travel distances. In the TUP, we are given a double round-robin schedule, and the task is to find an assignment of umpires to games such that every umpire handles at least one game at every team's home venue and an umpire neither visits a venue nor sees a team (home or away) more than once within a fixed number of time slots. The task is to minimize the total distance

traveled by the umpires. We show how it is possible to construct at the same time tournament schedules and corresponding umpire schedules that are constant-factor approximations for TTP and TUP, respectively.

■ TC-80
Tuesday, 12:30-14:00 - Architecture AR311, Level 3

Optimal Control and Mathematical Economics

Stream: Mathematical Economics
Invited session
Chair: *Alexander Zaslavski*

1 - Pontryagin Principles in Infinite Horizon with a Final Constraint
Joel Blot

We present new results on Pontryagin principles for infinite-horizon discrete-time optimal control problems in presence of an asymptotic condition on the state variable.

2 - Strongly Measurable Selectors of Multifunctions in Measure-Compact Banach Spaces
Nobusumi Sagara, M. Ali Khan

It is well-known that the lack of the separability assumption causes a serious difficulty to the classical measurable selection theorem of Kuratowski and Ryll-Nardzewski. Unpleasant objects in nonseparable topological spaces are found, for instance, in the following observations: (i) Caratheodory functions which are not jointly measurable; (ii) a failure of the measurable maximum theorem and the commutativity of the operations of supremum and integration; (iii) a discrepancy between scalarly and strongly measurable functions in nonseparable Banach spaces; (iv) the nonexistence of Walrasian equilibria and a failure of the core equivalence in the Bochner integral setting without the separability assumption on commodity spaces. We establish in this paper the existence of strongly measurable selectors of multifunctions in nonseparable Banach spaces. In stead of providing a criterion for a given scalarly measurable function to be strongly measurable, we pin down the structure of nonseparable Banach spaces in which every scalarly measurable function is scalarly equivalent to a strongly measurable function. This is accomplished through the use of measure-compact Banach spaces, which constitute an important class of nonseparable Banach spaces. Under the reasonable assumption on the cardinality of the density character for measure-compact Banach spaces, we show that every scalarly measurable, weakly compact-valued multifunction admits a strongly measurable selector.

3 - On the Regularity of Two Mappings in Optimal Control
Vladimir Veliov, Asen Dontchev

The talk will be about metric regularity properties of two mappings appearing in optimal control problems. We consider first the feasible set mapping of a nonlinear control system subject to state-control inequality constraints. Such systems arise often in the mathematical economics, as well as in many other applied areas. We give sufficient conditions for "regular" behavior of this mapping using the Robinson-Ursescu theorem in combination with a version of the Lyusternik-Graves theorem. Then we consider the optimality mapping for an optimal control problem with control constraints, and discuss the issu of regularity. Finally, we show how the regularity properties of the two mappings can be utilized for obtaining error estimates for discrete approximations.

4 - Structure of Solutions of Discrete Time Optimal Control Problems in the Regions Close to the Endpoints
Alexander Zaslavski

We study the structure of approximate solutions of an autonomous non-concave discrete-time optimal control system with a compact metric space of states. This control system is described by a bounded upper semicontinuous objective function, which determines an optimality criterion, and describes a general model of economic dynamics. In our recent research we showed that approximate solutions are determined mainly by the objective function, and are essentially independent of the choice of time interval and data, except in regions close to

the endpoints of the time interval. In this talk we study the structure of approximate solutions in regions close to the endpoints of the time intervals.

■ TC-82

Tuesday, 12:30-14:00 - Architecture AR401b, Level 4

Strategy Analytics

Stream: Strategy and Analytics
Invited session
Chair: *Frances O'Brien*

1 - Big Data and corporate strategy development
Frances O'Brien, Catrin Lewis

Big data has promised to transform the way we live, work and even sleep; yet despite improving efficiency and profitability in day-to-day tasks, little has been reported of big data permeating into higher level processes such as organisational strategic development. This paper reports current research in the form of a literature survey which explores how big data is being used to support corporate strategy development.

2 - A Complexity Perspective on the Role of Emotions in Determining the Outcome of Strategic Alliance Initiatives
Richa Joshi, Amanda Gregory

Stream - Area Soft OR and Problem Structuring Methods Sub-stream - Strategy and Analytics

Abstract The majority of strategic alliances fail and the dominant research perspective on these has not, so far, provided an adequate explanation for this nor instruction on how to avoid failure. Given this failure of the dominant perspective, we are compelled to look to insights offered by alternative perspective such as the complexity. Adopting a complexity perspective compels us to seek to be more holistic and brings to light the hitherto less considered aspects of combining two or more entities. Taking a case study approach, we use conditions of emergence posited by a complex systems approach (disequilibrium conditions, amplifying actions, recombination dynamics and stabilizing feedback; along with legitimate and shadow system view of organizations) to explore the post-integration phase of Mergers & Acquisitions (M&A) and International Joint Ventures (IJV) activity in an Indian pharmaceutical engineering firm. Our findings bring to light the importance of managing communication and emotional issues through such periods of strategic change. Adopting a recursive view of complex systems (with complexity manifested at different levels and interactions between levels) we are able to suggest measures for managing strategic alliances.

Key words — Mergers, Acquisitions, International joint ventures, complexity, dissipative structures, emotions

3 - OR&MS Supporting Strategic Development in the Airline Business
Juan Manuel Doblas Olmedilla

The paper analyses the use of Operational Research and Management Science to support different areas in the airline industry. The paper is divided in two parts: The first part provides an overview of the contribution ORMS makes to exploring and solving issues faced by airliners. This part summarizes the diverse areas currently covered by OR/MS in airlines. These areas are classified using the groupings: Revenue and Costs Management, Networking Planning, Operations Management and Supervision / Strategy. For each area, a summary is presented of the main contribution of OR/MS over the last decade. The second part focuses on strategy and future areas for research. This part focuses on supporting strategy development in the aviation sector. The purpose of this research is to explore opportunities in which OR/MS can contribute to the strategic design process applied to the airlines business. The paper includes suggestions for further research.

■ TC-84

Tuesday, 12:30-14:00 - Architecture AR403, Level 4

Health Care Emergency Management

Stream: Health Care Emergency Management
Invited session
Chair: *Christina Pagel*

1 - Optimality of the closest-idle policy in advanced ambulance dispatching
Caroline Jagtenberg, Sandjai Bhulai, Rob van der Mei

We address the problem of ambulance dispatching, in which we must decide which ambulance to send to an incident in real time. In practice, it is commonly believed that the 'closest idle ambulance' rule is the best choice and it is used throughout most literature. In this paper, we present alternatives to the classical closest idle ambulance rule. We show that significant improvements can be obtained by these alternative policies. The first alternative is based on a Markov decision problem (MDP), thereby constructing the first known MDP model for ambulance dispatching. Moreover, in the broader field of Dynamic Ambulance Management, this is the first MDP that models more than just the number of idle vehicles, while remaining computationally tractable for reasonably-sized ambulance fleets. Second, we propose a heuristic for ambulance dispatching that can handle regions with large numbers of ambulances. For both alternatives, we focus on two performance metrics, namely, the fraction of late arrivals and the average response time. We evaluate our policies by simulating a large emergency medical services region in the Netherlands. For this region, we show that our heuristic reduces the fraction of late arrivals by 18% compared to the 'closest idle' benchmark policy. This sheds new light on the popular belief that deviating from the closest idle dispatch policy cannot greatly improve the objective.

2 - Density adjusted probabilistic location problems in EMS
Martin van Buuren

To save lives, ambulances must arrive within a given time threshold. An indicator of the quality of service is the fraction of late arrivals. This is usually measured for an entire ambulance region on a yearly base, leading to outstanding coverage in cities at the cost of rural areas. We see a current trend shift that rural municipalities also demand a minimal fraction of late arrivals. This asks for a per demand point constrained facility location problem. However, current models like Q-MALP and Q-PLSCP give over-estimations for the required number of ambulances. We found the cause of this over-estimation called demand projection, and adjust the models such that they give more realistic ambulance allocations.

3 - A novel method to identify the start and end of the winter surge in demand for paediatric intensive care in real time
Christina Pagel, Padmanabhan Ramnarayan, Samiran Ray, Mark Peters

Implementation of winter surge management in intensive care is hampered by the annual variability in the start and duration of the winter surge. We aimed to develop a real-time monitoring system that could identify the start promptly and accurately predict the end of the winter surge in a paediatric intensive care (PIC) setting.

We adapted a statistical process control method from the stock market called "Bollinger bands' to compare current levels of demand for PIC services to thresholds based on medium term average demand. Algorithms to identify the start and end of the surge were developed using Bollinger bands and pragmatic considerations. The method was applied to a specific PIC service: the North Thames Children's Acute Transport Service (CATS) using eight winters of data (2005-2012) to tune the algorithms and one winter to test the final method (2013/14).

The optimal Bollinger band thresholds were 1.2 and 1 standard deviations above and below a 41-day moving average of demand respectively. A simple linear model was found to predict the end of the surge and overall surge demand volume as soon as the start had been identified. Applying the method to the validation winter of 2013/14 showed excellent performance, with the surge identified from 18th November 2013 to 4th January 2014.

An Excel tool running the algorithm is now used within CATS every day to monitor demand.

Tuesday, 14:30-16:00

■ TD-01

Tuesday, 14:30-16:00 - Barony Great Hall

Keynote Lecture: Eva K. Lee

Stream: Plenary, Keynote and Tutorial Sessions
Keynote session
Chair: *Christina Pagel*

1 - Optimizing and Transforming the Healthcare System
Eva Lee

Risk and decision models and predictive analytics have long been cornerstones for advancement of business analytics in industrial, government, and military applications. They are also playing key roles in advancing and transforming the healthcare delivery system. In particular, multi-source data system modeling and big data analytics and technologies play an increasingly important role in modern healthcare enterprise. Many problems can be formulated into mathematical models and can be analyzed using sophisticated optimization, decision analysis, and computational techniques. In this talk, we will share some of our successes in early disease diagnosis, treatment planning design, and healthcare operations through innovation in decision and predictive big data analytics.

■ TD-03

Tuesday, 14:30-16:00 - TIC Auditorium A, Level 2

OR careers exposition

Stream: Making An Impact 1 (MAI 1)
Invited session
Chair: *Ruth Kaufman*
Chair: *Ramune Sabaniene*
Chair: *David Lowe*

1 - OR careers exposition

Are you interested in what employment possibilities are 'out there', whether in academia or practice?

In this session, a variety of employers will be present to display information about their organisations, and to have informal conversations about the opportunities they may be offering in the short-to-medium term.

It is also an opportunity to make contact to set up a more formal one-to-one conversation, either at another time during the conference, or subsequently.

The list of employers will be available on the 'Making an Impact' section of the euro2015.org website, or on the 'MAI' desk at the conference, nearer the time.

■ TD-04

Tuesday, 14:30-16:00 - TIC Auditorium B, Level 2

Coordinating Pricing and Supply-Side Decisions

Stream: Operations/Marketing Interface
Invited session
Chair: *Candace Yano*

1 - Pricing and prioritizing time-sensitive customers with heterogeneous demand rates

Philipp Afeche, Opher Baron, Joseph Milner, Ricky Roet-Green

We consider the pricing/lead-time menu design problem of a profit-maximizing service where time-sensitive customers have demand on multiple occasions. Examples include amusement parks, museums, and ski resorts.

Customer types differ in two attributes, their demand rates and valuations per use. We study the case where customer attributes are private information and the case where the firm has full information. Customers queue for a finite-capacity service under a general pricing structure, and they choose a price/lead-time plan from the menu to maximize their expected utility.

In contrast to previous work, we assume customers do not differ in their waiting cost. Yet we show that in the private information case, prioritizing customers may be optimal as a result of demand rate heterogeneity. We provide necessary and sufficient conditions for this result. In particular, we show that for intermediate capacity, more frequent-use customers with a lower marginal value per use should be prioritized. Further, less frequent-use customers may receive a consumer surplus. We demonstrate the applicability of these results to relevant examples. The result implies that in some cases it may be beneficial for the firm to prioritize customers who have a lower marginal cost of waiting.

2 - Dynamic pricing and inventory management under network externality
Nan Yang, Renyu Zhang

We study a periodic-review joint pricing and inventory management model with network externality. The model considers a centralized firm which faces two demand segments in the market: (a) the leading segment, which exerts positive externality on demands from both segments; and (b) the following segment, which has no impact on the demand from either segment. To exploit network externality, the firm may charge different sales prices in different segments and offer free products in the leading segment. We show that a sales-dependent base-stock/offer-up-to/list-price policy is optimal. Network externality has several important impacts on the firm's optimal policy. First, under network externality, the optimal order-up-to level and the optimal list-price in each segment are increasing in the previous-period leading segment sales volume. Second, when ignoring network externality, the firm overestimates potential demand, and overprices its product in both segments. Third, an additional following segment prompts the firm to lower the sales price and offer more free products in the leading segment. We demonstrate that the commonly used introductory price strategy, free-product strategy and price discrimination strategy all effectively exploit network externality and improve the firm's profit. Finally, we generalize our base model to the model with accumulative network externality, where all past sales in the leading segment directly impact potential demands from both segments.

3 - The importance of integrating price and supply decisions
Peter Bell

It is not well known that price changes that increasing revenues may not increase profits while cost cutting campaigns may reduce costs but also reduce profits. This presentation uses a real case example to illustrate how these results arise and suggests that tightly integrated supply and marketing decision making is necessary for profit optimization. Such integration will improve operations level decisions and also provide an improved platform for tactical and strategic decisions.

4 - Optimizing pre-season orders with multiple planned promotions during the season
Candace Yano, Dimin Xu

Many clothing retailers place only one pre-season order with an overseas supplier for each product, but have plans for multiple promotions during the season, and ultimately will mark down excess inventory at the end of the season. Inventory is sent from the warehouse to retail stores weekly or perhaps more often, taking into account the impact of promotional prices and time-within-the-season on demands, with a view toward minimizing expected overage and shortage costs. We address the question of how to optimize the pre-season order quantity in view of the planned promotions, end-of-season mark-downs and the dynamic allocation of inventory.

■ TD-05

Tuesday, 14:30-16:00 - TIC Auditorium C, Level 2

Industrial Vehicle Routing

Stream: OR Applications in Industry
Invited session
Chair: *Geir Hasle*
Chair: *Gerben Groenendijk*

1 - On the Integration of Production and Routing Decisions

Stef Moons, Katrien Ramaekers, An Caris

Historically, production and distribution-routing problems are solved separately and sequentially. Unfortunately, this uncoordinated approach often does not lead to an overall optimal solution. Optimizing independently one problem disregards the requirements and constraints of the other. Extensive coordination among these stages in the supply chain is necessary for a high performing overall system. Integrating production and distribution operations can result in lower costs and a better service level. To integrate these two functions the classical vehicle routing problem (VRP) needs to be extended with production issues. An overview of the scarce literature on this topic will be provided. At the tactical decision level, lot-sizing decisions needs to be taken into account. For the so-called Production Routing Problem (PRP) some mathematical models are formulated in the literature. However, most of these models are based on less realistic assumptions to simplify the problem, e.g. single product, single plant, no time windows. At the operational decision level, the machine scheduling problem needs to be incorporated. Major part of the literature on production-distribution models allows only direct shipments to the customers. Only recently routing decisions are considered. A mathematical model for the operational level for the integrated production-routing problem will be presented and solved for small problem instances.

2 - A Novel Approach for a Real-life Multi-shift Full Truckload Vehicle Routing Problem

Ruibin Bai, Ning Xue

This paper introduces a bidirectional multi-shift full truckload transportation problem with operation dependent service times. The problem is different from the previous container transport problems and the existing approaches for container transport problems and vehicle routing pickup and delivery are either not suitable or inefficient. In this paper, a set covering model is developed for the problem based on a novel route representation. It was demonstrated that the model can be applied to solve real-life, medium sized instances of the container transport problem at a large international port. A lower bound of the problem is also obtained by relaxing the time window constraints to the nearest shifts and transforming the problem into a service network design problem. Implications and managerial insights of the results by the lower bound results are also provided.

3 - Real-life Vehicle Routing Problems: Gaps between Theory and Practice

Gerben Groenendijk, Leendert Kok

Generating high quality vehicle routes in practice is a challenging task. On the one hand, customers request more and more elaborate vehicle routing models to better fit their businesses. On the other hand, problem sizes grow, while the urge for finding solutions faster grows as well. Recently, the attention to rich Vehicle Routing Problems (VRP) has grown considerably in literature. Rich VRPs are highly evaluated in practice, since ignoring restrictions are very costly for at least two reasons. First, infeasible routes require (manual) rework. Second, more sound models lead to better evaluations of (intermediate) VRP solutions and therefore give better direction in the search for good VRP solutions. This better guidance for good VRP solutions often outweighs the extra calculation time needed for evaluating VRP solutions. I.e., evaluating fewer solutions in the same amount of computation time but with a better model fit often leads to better final solutions. Some constraints generally present in real-life routing problems have received only minor attention in literature. These constraints are more common than classical restrictions in literature such as time windows and capacity and have a high impact on the quality of vehicle routes. In this talk, we describe these gaps between theory and practice and illustrate how we cope with them in our vehicle routing solutions. Next, we discuss current major challenges in practice, which may serve as an agenda for future research.

■ TD-06

Tuesday, 14:30-16:00 - TIC Lecture Theatre, Level 1

POM II

Stream: Production and Operations Management
Invited session
Chair: *Jinwoo Park*

1 - Multiperiod production planning for closed-loop supply chain under the Internet-of-things scenario

Young-woo Kim, Jinwoo Park

Efficient operation of a closed-loop supply chain should be supported by reasonably good forward and reverse processes. However there exists the chronic problem of uncertainty about returned end of life (EOL) products with regard to timing, quality and quantity, which hin-ders the efficient operation of closed-loop supply chain. In this study, we present a frame-work of lifecycle data management system which gathers data of products and components under the Internet-of-Things (IoT) scenario. The proposed system enables information sharing among all entities in the supply chain and enables us to grasp the actual condition of the re-turned products with good accuracy. Thereby the proposed system helps us to improve the process for disassembly and product disposition to minimize cost of the total system. First, we develop a mathematical model of a closed-loop supply chain within the IoT-based infor-mation sharing environment consisting of a supplier, a manufacturer, and a reprocessing facili-ty in 3 different markets, namely original, refurbish and spare parts. Next we address a multi-period production planning model for multiple products consisting of multiple components with the objective of minimizing the sum of all incurred costs from the standpoint of a manu-facturer. We also analyze the behavioral characteristics of the model and conduct experiments to justify the proposed scheme.

2 - Twenty-six Years of Operations Management Research (1985-2010): Authorship Patterns and Research Constituents in Eleven Top Rated Journals

Timothy Fry, Brooke Saladin

This paper investigates the research contributions over a 26-year time frame (1985-2010) of academic institutions and individual authors to the field of Operations Management (OM). We use two measures, shared articles and distributed articles, to assess the research productivity of institutions as well as individual researchers. Further we assess the contribution of institutions based on affiliated author research as well as the research of their Ph.D. graduates. In order to accomplish this, we utilize the published OM research articles in 11 top-rated and well-known academic journals over the time period from 1985 to 2010. In addition to the research contributions of academic institutions and individual authors, we look at several bibliometric statistics related to this body of published research. These measures indicate that the research constituency is growing as evidenced by increasing numbers of researchers and institutions represented. Lastly, the collaboration between researchers appears to be increasing as evidenced by an increasing percentage of articles with three or more authors and the average number of authors per article published.

3 - The effect of operations strategies on performance-Applied research on the Egyptian pharmaceutical industry

Ahmed Attia

the current study examined the effect of different operations strategies (cost, quality, flexibility, and delivery) on the operational performance and the financial performance. The research hypotheses are:

H1: Operations strategies has a direct effect on operations performance. H2: Operations strategies has a direct effect on financial performance. H3: Operations performance has a direct effect on financial performance.

A questionnaire has been prepared and used to collect the data from the Egyptian pharmaceutical industries a total of 45 questionnaires has been filled by the companies, the total working companies at the Egyptian pharmaceutical industries are 61, so the respond rate was 73.7%.the analysis of collected date support the acceptance of three hypotheses.

4 - Make-to-stock or make-to-order? Optimal policies for supply strategies under uncertainties
Xiang Zhu, Liming Liu

We consider a single-stage firm, facing the choice of make-to-stock (MTS) and make-to-order (MTO) supply strategy. For a benchmark system with a Poisson demand process and exponential processing times, we prove that a utilization-threshold policy is optimal; i.e., if the utilization is above the threshold, the MTS strategy is optimal, and otherwise, the MTO strategy is optimal. When the demand process is not Poisson, the optimal policy is more involved but is still a threshold type, but the threshold depends on both the arrival variability and utilization. When the service time becomes general, the optimal policy is affected by supply variability, utilization, the waiting-time distribution, and cost parameters. Further, analytical and numerical results show that when demand uncertainty is high, the firm should follow the MTO strategy to be responsive to market while when the supply uncertainty is high, the firm should follow the MTS strategy to hedge the risk of breakdown and supply disruption.

■ TD-07

Tuesday, 14:30-16:00 - TIC Conference Room 1, Level 3

OR in Water Management and Natural Resources 2

Stream: OR in Water Management and Natural Resources
Invited session
Chair: *Jesse O'Hanley*
Chair: *Erdem Kilic*

1 - Hydraulic-Economic Model for Optimal Operation of Drinking Water Distribution Systems
Markus Siehlow

Operation of water supply is a vital part of society and complex task. The presented nonconvex mixed-integer nonlinear programming (MINLP) model can be used to find optimal supply strategies in operation of drinking water grids for cost and welfare if demand is fixed and variable, respectively. Furthermore, marginal costs at all nodes can be estimated and used to establish for instance a nodal pricing regime. Important hydraulic laws, operation aspects of network components (e.g., pipelines, pumps), economic aspects (e.g., demand curves) as well as a multitude of further technological and economic features are incorporated and combined within a coherent framework. The direct solving with the BARON-Solver, the Outer Approximation (OA), the Generalized Benders Decomposition (GBD), the Nonconvex Generalized Benders Decomposition (NGBD) and the NLP Relaxation are applied solution procedures to solve the original nonconvex MINLP. For the application of some solution procedures the factorization of some equations and the estimation of convex envelopes are required. These solution procedures as well as all the equations and inequalities of the model are implemented in the General Algebraic Modeling System (GAMS). The model is applied for a multitude of small-scale, medium-scale and large-scale networks (e.g., Berlin Drinking Water Grid). Information about performance of solution procedures, surpluses, consumption, marginal costs, operation modes, etc., is explained in detail.

2 - A Decision Support Tool for Transportation of Petroleum Products
Nergiz Haytural

The cost of logistic operations in oil and gas industry forms a significant part in total operation expenses. The paper discusses the decision support system covering the optimization of transportation network between two refineries in Turkey to minimize the overall transportation cost. The small one having low Nelson Complexity value is near the drilling area and its products need to be processed further. On the other hand, the complex one has been sending the final products to the small one which is also used as a terminal. Transportation of petroleum products can be carried out by road haulage, railroad, or by blending into crude oil pipeline. There are plenty of limitations due to the capacities, product specifications and policies of transportation agencies. Using mixed-integer linear programming, transportation planning is studied for monthly operations. With this decision support system, it is possible to make some scenario analysis like the increase in number of

available wagon, blending some amount of semi-products into crude-oil pipeline or establishing a wagon washing station. The optimized transportation plans are compared with operation results in 2013 and cost reductions up to thirteen percent can be obtained by applying different actions or investments.

3 - Optimizing the Location of Small Hydropower
Jesse O'Hanley, Christina Ioannidou

In this talk, we address the problem of locating Small Hydropower Plants (SHP) in an environmentally friendly manner. We propose the use of a multi-objective, mixed-integer programming model to maximize total hydropower production potential from SHP sites, while limiting their associated negative impacts on river connectivity. Critically, we consider the effect that downstream SHP sites have on power generation at upstream SHP sites via changes in water surface profiles, so called "backwater effects." We further account for the likelihood that migratory fish and other aquatic species can successfully pass multiple SHP sites. Although naturally represented in nonlinear form, we manage to linearize the problem by using a specialized network-flow structure, known as the "probability chain" method. Based on a case study from England and Wales, we illustrate the utility of our proposed framework in balancing tradeoffs between increasing renewable power generation and maintaining well-functioning river ecosystems. Critically, we show in the case of England and Wales, a region heavily impacted by a large number of existing river barriers, that installation of SHP sites which permit fish passage can in fact create a win-win situation that results in increased hydropower and improved river connectivity.

■ TD-08

Tuesday, 14:30-16:00 - TIC Conference Room 2, Level 3

Vendor Session IV: FICO

Stream: Vendor Sessions
Sponsored session
Chair: *Zsolt Csizmadia*

1 - Advances to modelling and deploying optimization applications with Xpress
Zsolt Csizmadia, Andrew Harrison, Susanne Heipcke

FICO Xpress Optimization Suite helps organizations develop and deploy optimization applications that solve the biggest real-world challenges faster than ever, leading to the best possible business decisions. It provides a complete software stack for building optimization solutions combining a broad set of high-performance solvers, an easy to learn and flexible modeling language and rapid application development capabilities.

Xpress-Mosel is a high-level algebraic modeling language that offers unique large scale optimization and enterprise features like distributed modeling and optimization, including in the cloud. New features of the Mosel language include the support of new data sources, such as HTTP, XML, JSON, encryption functionality for secure deployment in a distributed setting, automatic generation of documentation, and interfaces to statistics packages (R, Matlab).

Xpress optimization engines bundle a wide range of scalable, robust high-performance solver for linear, mixed-integer, non-linear and constraint programming.

In this session we will introduce recent developments like robust modeling and optimization, our approach for solving nonlinear problems and the new multi-start capability. We will also discuss new functionality for computing more accurate solutions and various improvements to the solver engines.

We shall also demo how to turn a Mosel model rapidly into a complete FICO® Optimization Modeler application for on-premise or cloud deployment.

■ TD-09

Tuesday, 14:30-16:00 - TIC Conference Room 3, Level 3

Vendor Session III: JMP and Simul8

Stream: Vendor Sessions
Sponsored session

Chair: *Ian Cox*
Chair: *Liam Hastie*

1 - Using Definitive Screening and Robust Optimization to Support 'Quality By Design'
Ian Cox

Quality By Design' (QbD) is an evidence-based approach to product development finally taking root in the pharmaceutical and related industries. A key issue in QbD is gaining the new process understanding required to reliably deliver the active drug substance at the micro (single patient) and macro (manufacturing system) level. This presentation shows how a new class of statistically designed experiments, coupled with the stochastic optimization of critical to quality characteristics, can support this endeavour in an efficient way. Examples will be shown using JMP, Statistical Discovery software from SAS.

2 - SIMUL8 Simulation Innovations
Liam Hastie

SIMUL8 has helped major organizations across the world for over 20 years — saving money, reducing waste and improving efficiency. Used by over 70% of Fortune 50 companies to improve their performance, SIMUL8's powerful simulation software is fast to learn and flexible enough to be used for a wide range of applications. Come along to our presentation and learn how SIMUL8 can help you find solutions for your most challenging problems, communicate decisions and take your process off the page so others can see the value simulation brings to your organization. This will include a demonstration of some of our research breakthroughs incorporated in our latest public release.

■ TD-12

Tuesday, 14:30-16:00 - TIC Conference Room 4&5, Level 3

Bioenergy Challenges for a Future Low Carbon Energy System

Stream: Long Term Planning in Energy, Environment and Climate
Invited session
Chair: *Seungwoo Kang*

1 - Application of Fuzzy Goal Programming to Sugarcane Harvest Planning Problems
Fernando Marins, Aneirson Silva, José Roberto Dale Luche, Erica Dias

This paper presents a fuzzy goal programming (FGP) model for sugarcane harvest planning under uncertainty. The proposed FGP model includes the agricultural stage, the choice of sugarcane conditions, harvest timing, the cutting and transportation processes of the sugarcane to the plant. The model solution includes cutting the sugarcane in the time closest to maximum sucrose content, and minimizes the involved costs. In a real application, the model allowed identify among the involved objective functions those ones are more sensitive to uncertainty and it generated useful scenarios for the plant managers helping them to do harvest planning under uncertainty.

2 - Multi-objective Mathematical Model Applied to Biodiesel Supply Chains Management in Colombia
Javier Arturo Orjuela Castro, Johan Alexander Aranda Pinilla

Biofuel production has been growing steadily in recent years, driven mainly by the environmental benefits they bring in comparison with fossil fuels. However, there are concerns about the impacts on food safety that their production and distribution can generate. A model of multi-objective linear programming to make strategic decisions associated with the production of biodiesel from palm oil in Colombia is proposed. The model simultaneously optimizes the total cost of the chain, the impact on food safety and emissions of greenhouse gases, including emissions by direct and indirect land use change. The model considers four stages of the supply chain in Colombia (planting, extraction, bio-refining and mixing) and allows establishing a distribution plan for palm, oil, bio-diesel and diesel along the chain as well as production and inventory plans. Results show the resulting trade-off between environmental, food security and economic objectives and they allow, using scenarios, develop sustainability strategies between cost, environment and food security in a planning horizon of 30 years.

3 - India's long-term pathways for bioenergy: scenario analysis using TIAM-FR model
Seungwoo Kang, Sandrine Selosse, Nadia Maïzi

The third largest GHG emitter in the world after China and the USA, India is facing climate change challenges. In 2012, Indian government announced their voluntary GHG emission abatement target for 2020 and is expected to submit in 2015 its Intended Nationally Determined Contributions (INDCs) to the next Conference of Parties (COP 21) in Paris. In their actions against climate change and to reduce GHG emissions, renewable energy including bioenergy is being highlighted. Bioenergy plays also an important role for Indian energy security. The poor energy access in remote areas made India invest in the bioenergy development through off-grid and decentralized energy systems from biomass. Moreover, growing demand in electricity and transport fuel raised also strong needs of bioenergy. This study evaluates possible pathways of development of low carbon energy system using the multi-region energy system model TIAM-FR, the French version of the TIMES Integrated Assessment Model, developed under the IEA's ETSAP (Energy Technology Systems Analysis Program). This bottom-up optimization model allows technology-rich representation of energy system, so, under various scenarios, the feasibility of the current Indian energy and environmental policies ,and the most economic-technological pathways have been analyzed, including notably their technical and economic viability that slows down the bioenergy development as well as limited feedstock.

■ TD-15

Tuesday, 14:30-16:00 - TIC Conference Room 6&7, Level 3

Risk and Disruptions

Stream: Supply Chain Management
Invited session
Chair: *Stefan Nickel*

1 - Consignment Contract in a Supply Chain of Mobile Applications under Risk Consideration
Tatyana Chernonog, Yael Perlman, Tal Avinadav

We analyze pricing and quality investment strategies in a two-echelon supply chain of mobile applications (apps) under a consignment contract with revenue sharing. Specifically, we focus on how risk-sensitive behavior of supply chain members affects chain performance. The platform provider sets the level of revenue sharing, and the app developer determines the investment in quality and the selling price of the app. The demand for an app, which depends on both price and quality investment, is assumed to be uncertain, so the risk attitude of the supply chain members has to be considered. The members equilibrium strategies are analyzed under different attitudes toward risk: averse, neutral and seeking. We show that the retailer's utility function has no effect on the equilibrium strategies, and suggest schemes to identify these strategies for any utility function of the developer. We find that (i) the revenue sharing contract circumvents the double marginalization effect associated with vertical competition and therefore yields the best selling price for the customer; (ii) a decentralized supply chain sometimes performs better than a centralized one; and (iii) a risk-seeking developer may obtain a higher expected profit than does a risk-neutral developer.

2 - Market Share Recovery Dynamics in the Aftermath of Substitute Supply Chains Disruptions: A System Dynamics Approach
Christos Keramydas, Eleftherios Iakovou, Dimitrios Vlachos

As competition between brands has turned into competition between supply chains (SCs), substitution between brands has also evolved into substitution between SCs. In competitive environments, supply disruptions in tandem with consumers' response to stockouts have a critical role on the strategic performance of supply networks and their sustainability. Thus far, the impact of supply disruptions on a company's market share and profitability has not been addressed satisfactorily in the literature. In this research, we capture quantitatively the merit of substitute SCs within a risk management context, considering the critical supply disruption characteristics, i.e. frequency and severity, and market shares of the SCs involved. Following that, a system dynamics (SD) methodology is proposed in order to quantify the dynamics of the recovery process of substitute SCs in the aftermath of a disruption,

in terms of market share, time, and cost to recover. An integrated approach is also adopted, based on well-established literature insights in order to merge short-term consumer responses to stockouts with their long-term brand choice. Numerical investigation indicates that factors such as brand loyalty, supply capacity, frequency and severity of disruptions have an important role in the market share recovery process of a SC. Finally, the impact of alternative logistics-based risk mitigation and marketing-based strategies towards regaining market share are also documented.

3 - How Supply Disruptions and Varying Leadtimes Hurt Spare Parts Supply Chains

Rommert Dekker, Mustafa Hekimoglu, Erwin van der Laan

From empirical analysis of an asset maintenance organisation it appears that for ageing aircraft parts supply leadtimes vary widely and can be disrupted by supplier defecting. To overcome these problem we develop a Markov modulated inventory control model which covers these characteristics. We establish optimality of base stock policies and provide algorithms to calculate average costs, supply risks and optimal base stock levels. Using real data we show the working of the model. Next we investigate what is more effective: predicting supply failures or solving them quicker.

4 - A Simulation-based Supply Chain Risk Analysis Framework

Iris Heckmann, Stefan Nickel

The literature on supply chain risk analysis is mostly of anecdotal or case-based nature (Chopra & Sodhi 2004, Norrman & Jansson 2004) and only few authors present empirical research (Wagner and Bode 2006). Quantitative, systematic and reliable analyses are scarce. Mathematical optimization approaches focus on a small number of variables and, therefore, are less suitable to model numerous interacting characteristics, which prevail in nowadays supply chain systems. Instead, simulation is more appropriate as a method to model and analyze complex systems. In this work we present a new simulation-based approach for the analysis of supply chain risk. The main goal of the presented simulation model is to provide the user with valid and credible implications on the dynamics that drive the underlying supply chain and that potentially make supply chain risk effective when disturbances occur. For the sake of conceptual and methodological consistency the risk analysis approach models and respects the defining entities of supply chain risk (Heckmann et al. 2015). The simulation is built around an operational planning system and provides the decision maker the possibility to establish a continuous improvement process: Lessons learned from the risk analysis can be adopted for risk-reducing measures in the operational system. In order to demonstrate the functionality of the framework, we elaborate and present a case study.

■ TD-16

Tuesday, 14:30-16:00 - TIC Conference Room 8, Level 3

Lot Sizing in the Supply Chain

Stream: Lot Sizing, Lot Scheduling and Related Problems
Invited session
Chair: *Christian Almeder*
Chair: *Christophe Rapine*

1 - Joint sales and production planning in a multi-stage batch production environment

Peeyush Mehta, Pankaj Chandra, Devanath Tirupati

In this research we consider a production-planning problem in a complex multi-stage, batch-processing environment characterized by production of finished goods, intermediate- products, and by-products. A critical resource in the production environment is the recycling facility where some of the by-products are reprocessed and reusable raw materials are recovered. The recovered raw materials are used back in the production process along with fresh raw materials specified by the stringent quality requirements observed in a bulk drug production facilities. The existing production planning by the firm is done on the basis of firm orders and monthly demand forecast over a finite planning horizon. The firm faces problems of high finished goods inventory of some products and shortages of others. The products are produced

on production lines that allow sharing of equipments with significant changeover time between two products. The problem is motivated by a real-life application involving a bulk-drugs manufacturer. We develop mathematical models to determine the production planning decisions. The proposed models indicate significant improvement in the production planning costs over the existing results. We also integrate the sales and production planning decisions and show that significantly higher benefits are realized through joint optimization of sales and production planning over the traditional production-planning tools.

2 - Limitations of linear programming in the supply chain

Bertrand Hellion

Advanced planning software (APS) editors have been convinced by linear programming (LP). In our company, most of the used algorithms are LP-based, and there is strong assumptions that the other APS editors choose the same path.

In this presentation, some major features of the LP-based algorithms are discussed.

1) Many industrial constraints cannot be modelled by linear equations.

2) Linear programming is optimizing a cost function to reach an optimal solution. In this cost function the different objectives are weighted, so they can compensate each other. This compensation only makes sense if all the industrial costs are known, which is likely not to be.

3) In their work, all theses users use to think in term of priority and risk. The solutions found by a LP-based algorithm are extreme, by definition. If the algorithm must produce X items A and Y items B, but has the capacity for only one of those types of products, the LP-based algorithm always produce either A or B. A supply chain professional would decide to produce a half batch of A, and a half batch of B, knowing that the demand can vary. By doing this, he limits the risks he takes. He does not optimize a cost function.

4) Minor parameter changes can drastically change the solution. The user, who is mostly not an Operational Research professional, would have some trouble to clearly understand how the algorithm find its solution.

3 - Lot streaming in a vertically differentiated supply chain

Tulin Inkaya

Companies offer product variety in order to satisfy the needs of heterogeneous customers. Traditional approaches consider the product variety decisions from the marketing perspective only. In this work, we jointly investigate the marketing and operational aspects of the problem in a supply chain scheduling framework. We consider a vertically differentiated supply chain, in which end customers are heterogeneous in the sense that they are willing to pay more for products with higher quality. In order to make the products flow faster through the supply chain and to decrease the work-in-process inventory, we use lot streaming to coordinate the transfer lots between a manufacturer and its supplier. A mathematical model is proposed to determine the optimal number of transfer lots, and the benefit of lot streaming is analyzed. We also study how the lot streaming decisions affect the product variety and quality level decisions. Numerical experiments are performed to illustrate the impact of production costs, processing times, and customer valuations on the product variety and lot streaming decisions.

4 - Multi-mode replenishment lot sizing problem with batch deliveries

Christophe Rapine, Ayse Akbalik

We consider in this presentation the single-item uncapacitated lot sizing problem with multi-mode replenishment and batch deliveries. In practice, this problem corresponds to the situation where a firm can place orders to different suppliers in each period, and the quantities ordered from a supplier are delivered by batch (typically truck size or container). Each supplier incurs a specific procurement cost, including a fixed ordering cost plus a fixed cost per batch, known in the literature as the Full Truck Load (FTL) cost structure. The size of the batches may differ from one supplier to another. This problem can also be seen as a one vendor-one buyer problem with different transportation modes (small, medium or large trucks, train, barge, ...) available to ship the units between them. When batch delivery is not considered, that is with affine procurement costs, the problem is known to be polynomially solvable for stationary cost parameters. In contrast we establish that under the FTL cost structure, the problem is NP-hard even when restricted to a single period. We give some approximation results and propose a polynomial time algorithm for the case where only 2 modes are available and their batch sizes are divisible.

■ TD-17

Tuesday, 14:30-16:00 - TIC Conference Room A, Level 9

IBM Research Applications III

Stream: IBM Research Applications
Invited session
Chair: *Odellia Boni*
Chair: *Marco Laumanns*
Chair: *Martin Mevissen*

1 - Convex Relaxation of Optimal Hydroelectric Power Production Scheduling
Leonardo Martins, Secundino Soares

Hydroelectric power production scheduling is concerned with planning optimal electricity generation at hydro plants so that economic welfare is maximized over a period of time, while system load demand is satisfied subject to operation constraints. The multifaceted complexity of the problem derives from the sheer large-scale nature of power systems, space-and-time coupled operation of reservoirs, nonlinear relationships between its compounding models, as well as uncertainties associated with future operation. It has been traditionally proposed in the literature to decompose the problem in its time dimension into properly coordinated shorter- and longer-term subproblems, focusing on different aspects of each time frame by taking into consideration different objectives and constraint sets, and making different assumptions. In this presentation, we introduce the mathematical formulation for both shorter- and longer-term scheduling and how convex relaxation by semidefinite programming can be used to solve this problem. In the longer-term case, we formulate optimal reservoir operation scheduling as a nonconvex homogeneous quadratic problem, whereas in the shorter-term case, we formulate optimal hourly unit commitment scheduling as a mixed-integer quadratically-constrained quadratic problem with AC power flow network constraints. Additionally, we provide both theoretical and numerical results that support the effectiveness of the application of convex relaxation to the problem.

2 - Wind-hydro Integration Stochastics Engine (WhISE)
Ali Koc, Soumyadip Ghosh

Integration of renewables into the aggregate generation portfolio is a key focus for electricity generation companies. Renewable energy from sources such as wind and solar radiation are subject to stochasticity and intermittency, which creates a fundamental challenge in integrating these sources and ensuring that overall provisioning of generation is managed robustly. We describe a stochastic planning engine (Windhydro Integration Stochastics Engine WhISE) developed jointly by IBM Research and IREQ, the research division of Hydro-Québec. WhISE generates a day-ahead unit commitment plan for hydro-turbines and helps decide the optimal dispatch of the hydro capacity to meet per-hour demand such that the expected end-of-day value of an overall operational performance metric is minimized. WhISE takes historical demand and wind realizations as input, creates a forecast model based on dynamic linear modeling. A set of scenarios (sample paths through time) of possible realizations of renewable generation are then sampled from this forecast model. A key innovation is the day-ahead planning and multi-period dispatch problem in WhISE, which is modeled using a twostage stochastic programming formulation. The first stage makes decisions that set the turbine commitments for each hour of the next day. The second stage models the realized turbine commitments and arc flows by choosing optimal values from within the range of allowed operation of the committed turbines.

3 - Sparse Polynomial Optimization for Urban Distribution Networks
Martin Mevissen

In many optimization problems over urban distribution networks, the decision maker faces the combined challenge of nonlinear constraints, system parameters affected by uncertainty, and the scale of the underlying network. However, such problems also exhibit structure, notably sparsity, which can be exploited in order to improve the scalability of polynomial optimization solvers. On challenging problems including AC optimal power flow and pressure management in water networks, we demonstrate an approach, which combines efficient mathematical modelling, and exploiting sparsity in both, the polynomial optimization formulation and its SDP relaxations.

■ TD-18

Tuesday, 14:30-16:00 - TIC Conference Room B, Level 9

Energy Market Modeling 5: Optimization and Power Systems

Stream: Energy Market/System Modeling
Invited session
Chair: *Juan Miguel Morales*
Chair: *Marco Zugno*
Chair: *Kevin Münch*

1 - Optimal Topology of Electricity Transmission Network for Reducing Economic Harm from Market Power
Mohammad Reza Hesamzadeh, Yaser Tohidi

This paper shows how the optimal transmission network configuration can reduce the economic harm from market power. The strategic generating companies are modelled using a Nash-Cournot game. To tackle the multiple Nash equilibria problem, the solution concept of the extremal-Nash equilibria (ENE) is introduced. The ENE solution concept is formulated as an equilibrium problem with equilibrium constraint (EPEC) and then linearised as a mixed-integer linear program (MILP). The network switching decisions are modelled as binary variables controlled by the regulated network operator. The network operator minimises the system dispatch cost calculated at extremum-Nash equilibrium using its network switching decisions. The network operator problem is a mixed-integer bilevel linear program (MIBLP) with integer variables in both upper and lower levels. The upper-level is the network operator and the lower-level is the strategic generating companies. A depth-first branch-and-bound technique is used to solve the developed MIBLP model. An illustrative 3-node and the IEEE-RTS96 example systems are studied. The numerical results demonstrate that the utilisation of the optimal transmission switching policies increases economic benefit and improves competitiveness in the liberalised electricity markets.

2 - Analysis of the Nigerian Electricity System using Optimal Load Shedding
Alastair Heggie, Ken McKinnon

The generation capacity of Nigeria's electricity system is underutilized despite the system failing to meet demand. A strategy of minimizing the total amount of load shed leads to severe shortages in some Distribution Company (DISCO) regions. In this study we use an AC optimal load shed (OLS) model, a non-linear non-convex optimization problem that accurately models the voltages and power flows in the Nigerian network, to investigate the transmission problems limiting supply and the conflicts that exist between supplying different regions.

We first find the minimum load shed over the entire country by solving the OLS with equal load shed penalties in all DISCOs. Then, by increasing the load shed penalty for each DISCO in turn, we find how increasing the load supplied into one DISCO affects the optimal supply to the other DISCOs, and also identify those DISCOs for which it is impossible to satisfy their load independent of what is supplied elsewhere.

We demonstrate the trade off between reactive power support added to the network and load shed and show how the optimal distribution of extra reactive power depends on the investment costs and their degree of concavity. For the modelled loads limited reactive support at a small number of buses can eliminate all load shedding, however, for the future expected loads, load shedding cannot be avoided without increasing transmission capacity or building new generators in areas of shortage.

3 - Forecasting CO2 emissions related with fossil fuel consumption in Turkey
Selim Ceylan, Zeynep Ceylan, Seniye Ümit Oktay Fırat

The increase in population and industrialization has caused global warming due to emissions of greenhouse gases (GHG). The carbon dioxide (CO_2) is the main component of GHG which is mainly formed by fossil fuel consumption. Energy production in Turkey is mainly depends on fossil fuels. Therefore, the primary source of CO_2 emissions in Turkey is the consumption of fossil fuels. Thus, energy policy of the country and environmental regulations must depend on amount of CO_2 emissions. In this study, Artificial Neural Network (ANN) was used to

forecast amount of CO_2 emissions related with consumption of fossil fuel sources (coal, liquid fuel and natural gas). ANN analysis was performed using various learning algorithms with different parameters to obtain high correlation coefficients. The input data of coal, liquid fuels and natural gas consumption and population were collected from Turkey Statistical Institute (TURKSTAT) between years 1985-2013. The best model was chosen to predict CO_2 emissions of Turkey up to 2020.

4 - Mixed-Integer Programming Approach to Minimize the Costs of Balancing Energy in Natural Gas Transport Networks

Kevin Münch, Albert Moser

The liberalization of the European gas market allows a more flexible usage of natural gas transport networks by the customers. The central task for the network operator to maintain the minimal and maximal pressure during transport. To ensure acceptable pressure levels, the usage of balancing energy provided by third parties is often necessary and increases as consequence of need for more flexible network operation. Therefore, an experience-based usage of balancing energy is no longer possible. Hence, this work develops a computer-aided optimization to determine the minimum cost of use of balancing energy by linear programming. For example, natural gas storage has a fill level based injection and withdraw rate or minimum operation times and so mixed-integer linear programming approach is necessary. Therefore, in the first step, this work analyses the technical constraints of the natural gas transport network, especially the pressure borders, and possible assets for balancing energy. In the next step, the works formulates a mixed-integer problem to consider every necessary constraint and solves it using a branch-and-cut algorithm. In the last step, exemplary results verify the solution and allow a discussion about the advantages of using developed optimization solution for a natural gas transportation network.

■ TD-24

Tuesday, 14:30-16:00 - John Anderson JA3.25 Lecture Theatre

MCDM Applications

Stream: MCDM
Invited session
Chair: *Valentina Ferretti*
Chair: *Marta Bottero*

1 - Smart lands from the perspective of the green-web. Signification, information and communication in a WebGIS-DRSA valuation/selection pattern for slow mobility

Salvatore Giuffrida, Filippo Gagliano, Maria Rosa Trovato

Information is the most general value-substance in the contemporary social-economic system. A "smart land pattern' assumes information as both raw material and final destination of the communicative process, that is the process within environment, land and landscape are connected by means of the category of value. In an economic pattern, information needs to be meant as the general category of shape, organization, programming, aimed at improving the performances of the allocation pattern. Slow mobility is the segment of land economy in which information can be assumed as a "low-cost' input and, at the same time, the most connotative output, "the territory shape'. In this second role, information needs to be assumed as a communication pattern. In this work, concerning two different wide areas in Sicily, we propose an information, valuation and communication pattern based on a Web-GIS interface incorporating a MAVT valuation support, connected with a DRSA pattern aimed at handling the interaction between users and decision makers. This pattern is helpful to the environmental landscape policies, since it allows: - users to select and to define the best path according to their axiological profile, their individual preferences; - appraisers/planners to adjust the valuation pattern and the land values map; - decision makers to specify the land policies by means of interventions taking into account the interaction with users through an adaptive preferences pattern.

2 - Testing alternative methods for a composite indicator of territorial vulnerability

Alessandra Oppio

Planning processes even more call for procedures aimed to consider the environmental issues within decisions regarding high impact interventions. Changes in land use and socio-economic characteristics are likely to decrease the capability of a territory, meant as an ecosystem, to provide vital services for people and society. In this context the concept of territorial vulnerability is a key concept, whose assessment could support decision makers to achieve sustainability targets. The research has a double aim. Firstly, from a methodological point of view, to define a Territorial Vulnerability Index and to verify its robustness by the analysis and implementation of alternative methods for constructing composite indicators. Secondly, to test the uselfuness of such an index as a supporting tool for policy making. The research has been developed according to three different phases: 1. Definition of a multidimensional Territorial Vulnerability Index (TVI); 2. Analysis of alternative methods for constructing composite indicators; 3. Application of different models of Vulnerabilty Index to Lombardy region (Italy) Advantages and disadvantages of composite indicators have been deeply analyzed with reference to the variability of results depending on the standardization and aggregation methods selected. Although the empirical analysis should be validated by furher applications, it has been demonstrated that the TVI is a promising tool for policy making.

3 - A multi-stakeholders decision process to support urban planning strategies

Marta Bottero, Valentina Ferretti

Urban planning can be regarded as a multifaceted concept which includes socio-economic, ecological, technical, political and ethical perspectives. Under these circumstances, the evaluation of alternative urban planning scenarios is therefore a complex decision problem (Prigogine, 1997; Simon, 1960) where different aspects need to be considered simultaneously, taking into account both technical elements, which are based on empirical observations, and non technical elements, which are based on social visions, preferences and feelings. This paper aims at exploring the method of Social Multi-Criteria Evaluation (SMCE, Munda, 2004) which combines Multicriteria Decicison Analysis (MCDA) with institutional and social analysis. SMCE is based on an interdisciplinary approach able to analyze the problem considering the different disciplines and dimensions involved; moreover, SMCE proposes a transparent and participated process, which enables the inclusion of the local community and thus increases the democracy of the evaluation process. In the research the SMCE was applied on a real-world problem concerning the requalification of a suburban area in the city of Torino (Italy). In the evaluation different scenarios were compared on the basis of several criteria, such as economic costs, services, mobility, etc.; moreover, the evaluation included the opinion of the different stakeholders playing a role in the problem under examination.

■ TD-25

Tuesday, 14:30-16:00 - John Anderson JA3.14 Lecture Theatre

Environmentally Responsible Supply Chains

Stream: Environmental Sustainability in Supply Chains
Invited session
Chair: *Maria Besiou*

1 - Emission Reduction through Speed Optimisation in Global Supply Chains

Michele Acciaro

Greenhouse gas (GHG) emission reduction along global supply chains has become increasingly important, and efforts are being carried out in the liner shipping industry to reduce its maritime carbon footprint. One of the major operational strategies employed by ocean carriers is speed optimisation, so that vessel capacity, speed and service frequency can be adjusted to deliver emission reduction, in general with sizable benefits to the firm bottom-line. While the implications of speed optimisation for the industry and for cargo interests are in general well understood, the interrelations between speed optimisation and optimal vessel size are often overlooked. Moreover haul length, cargo value and fuel costs, as well as other operational parameters, are critical in the determination of optimal speed and vessel size. In this manuscript optimal speed and vessel size are analysed as a function of other operational parameters. Through simulation, the paper shows that the

GHG emission reduction generally attributed to speed optimisation is in reality the result of a joint optimisations of operations, where vessel deployment, network design and demand characteristics play a critical role. The paper main finding is that speed optimisation alone is not a sufficient condition for emission reduction, and that particular attention should be paid to the opportunity cost of cargo in transit and the availability of capacity.

2 - Life-Cycle Planning in Closed-Loop Supply Chains: A Study of Refurbished Laptops
Thomas Nowak, Gernot Lechner

As waste electrical and electronic equipment is one of the fastest growing waste streams, the reduction of discarded electronic equipment is of immense importance in order to reduce virgin material consumption and hence the environmental impact. Using the market for new and refurbished laptops as a reference industry, we present a newsvendor model with price effects and return flows of products that allows the original equipment manufacturer (OEM) to outsource product recovery operations to a third party reverse logistics provider. Based on an empirical study on pricing decisions of new and refurbished laptops, we are able to use a realistic parameterization of our model and, hence, to derive insights on the relationships between consumer awareness towards refurbished products, their return behavior as well as optimal reverse logistics decision making of an OEM.

3 - The Impact of Shelf Life Agreements on Service Levels and Waste in Perishable-Product Supply Chains
Sandra Transchel

We study a two-echelon supply chain consisting of a manufacturer and a retailer that sell a single product with a fixed limited shelf life. Manufacturer and retailer negotiate a contract comprising a wholesale price, a shelf life agreement (a maximum remaining product shelf life that the manufacturer needs to guarantee to the retailer), and service level agreement (a minimum service level requirement the manufacturer needs to fulfill). The retailer follows an inventory policy with the objective to satisfy a predetermined service level to the market. The manufacturer faces fixed manufacturing cost and aims to leverage economies of scale by producing larger lot sizes. However, due to the perishable nature of the product and the shelf life agreement with the retailer, the manufacturer is not able to fully leverage economies of scale. Moreover, both firms face a negative impact on the level of waste in the supply chain. We develop an inventory model and study supply chain contracts between the manufacturer and the retailer. We study the interaction between wholesale price, shelf-life agreement, and service level agreement, and investigate the impact on profitability and waste efficiency of the individual firms as well as the overall supply chain.

4 - On the Attractiveness of Product Recovery: The Forces that Shape Reverse Markets
Dennis Stindt, Joao Quariguasi, Christian Nuss, Martin Dirr, Marta Jakowczyk, Andy Gibson

Product recovery is worth billions of dollars. However potentially lucrative, the management of product backflows is known to strongly increase the complexity and cost structure of supply chains. In many cases, practitioners face strategic issues concerning reverse market entry and positioning. Yet, to this date, a comprehensive framework that facilitates informed decision-making in the area of product recovery is missing. In light of that, based on a comprehensive literature analysis, in-depth interviews and industry engagements with 12 OEMs and independent recovery companies based in Germany and the UK, and drawing from the Porter Five Forces model, we develop a model to assess the attractiveness of product recovery by depicting the forces that shape reverse markets. To demonstrate how such a model could be deployed in practice, we apply it to two different industries: recovery of white goods in the UK and paper recycling in Germany. Drawing on the model developed in this study, we propose 100 questions that should be considered by managers who plan to engage in product recovery. Essentially, this research enables practitioners to understand the structure and driving forces of reverse markets, to identify levers to influence the market, to anticipate market developments, and to formulate resilient strategies.

■ TD-26
Tuesday, 14:30-16:00 - John Anderson JA3.17 Lecture Theatre

Nonconvex Programming: Local and Global Approaches

Stream: Nonconvex Programming: Local and Global Approaches
Invited session
Chair: *Hoai An Le Thi*

1 - DC programming and DCA for the piecewise linear optimization
Vinh Thanh Ho, Hoai An Le Thi, Tao Pham Dinh

Piecewise linear optimization is one of the most frequently used optimization models in practice, such as transportation, finance and supply-chain management. In this paper, we investigate a particular piecewise linear optimization that is optimizing the norm of piecewise linear functions (NPLF). In general, the NPLF is considered as an optimization problem with a nonsmooth, nonconvex objective function. A new and efcient optimization approach based on DC (Dierence of Convex functions) programming and DCA (DC Algorithms) is developed. We are interested in solving a class of piecewise linear systems (PLS), known as an NPLF problem, especially, in the free-surface hydrodynamic problem whose correct numerical modeling often requires to have the solution of special PLS. Numerical experiments in a homogeneous isotropic aquifer show the efficiency of our proposed method.

2 - DC Programming and DCA for Rank-Two Beamforming and Power Allocation in Multicasting Relay Network
Thi Thuy Tran, Hoai An Le Thi, Tao Pham Dinh

This paper concerns a single-group multicasting relay network comprising of multiple amplify-and-forward relays forwarding signal from a single source to multiple destinations. The source, relays and destinations are equipped by single antennas. In this scenario, we deal with the problem of maximizing the minimum Quality of Service (QoS) assessed by the Signal to Noise Ratio (SNR) of the destinations subject to power constraints. This problem is actually a nonconvex optimization one, which can be reformulated as a DC (Difference of Convex functions) program with DC constraints. We will first turn this program into a standard DC program and apply then the standard DCA (DC Algorithms) for solving it. Numerical experiments are carried out on several networks simulated under realistic conditions.

3 - Robust Principal Component Analysis via DC Programming and DCA
Hoai Minh Le, Xuan Thanh Vo

Robust Principal Component Analysis (RPCA) is a modification of the widely used procedure Principal component analysis (PCA) which works well with corrupted observations. RPCA has many real life important applications such as Video Surveillance, Face Recognition, ... RPCA solved via Principal Component Pursuit (PCP) decomposes a data matrix A in two components such that A=X+Y, where X is a low-rank matrix and Y is a sparse noise matrix. The problem can be modeled as a minimization of the trade-off between the zero-norm of Y and the rank of X, which can also be expressed as the zero-norm of singular values, subject to the model fitness. The problem is intrinsically combinatorial so it is NP-hard in general. In this work, the zero-norm is approximated by a non-convex continuous function. The resulting problem is then reformulated as a DC (Difference of Convex function) program and solved by DC Programming and DCA (DC Algorithm). Experimental results on synthetic and real data sets showed the efficiency of our DCA-based algorithm.

4 - Robust Optimization for Clustering Problem
Xuan Thanh Vo, Hoai An Le Thi

The aim of this study is to investigate the robust optimization for clustering problem. We consider the minimum sum-of-squares clustering model and assume that each data point belongs to a box-type uncertainty set. Following the robust optimization paradigm, we obtain a robust formulation that can be interpreted as a combination of k-means and k-median clustering criteria. An algorithm based on DC (Difference of Convex functions) programming and DCA (DC Algorithm) is developed to solve the resulting robust problem. Preliminary numerical results on synthetic and real datasets show that the proposed robust optimization approach is superior to k-means and k-median clustering approaches.

5 - Parameter Estimation for Latent Log-Linear Models as DC Programming
Hoai An Le Thi, Duy Nhat Phan

In machine learning and pattern recognition, latent variables are used in many applications such as speech recognition, information retrieval, natural language processing and object recognition. We present a novel approach for a log-linear model incorporating latent variables. The parameter estimation of this model results in an optimization problem involving a rational function of mixtures of exponential terms. It is a nonconvex and large-scale problem which is very hard to solve. We overcome these difficulties by reformulating it as a DC (Difference of Convex functions) program to which DC programming and DC Algorithms (DCA), an efficient approach in nonconvex programming framework, will be investigated.

■ TD-27
Tuesday, 14:30-16:00 - John Anderson JA3.27, Level 3

Vector and Set-Valued Optimization I

Stream: Vector and Set-Valued Optimization
Invited session
Chair: *Lidia Huerga*

1 - Approaches to Criticality of Vector-Valued Mappings
Ewa Bednarczuk

The concept of criticality is one of the basic concepts of the variational analysis. For vector-valued mappings the most commonly used concept of criticality has been proposed by Smale for continuously differentiable mappings and ordering cones possesing nonempty interiors.

In the present talk we discuss generalizations of the concept of criticality in the sense of Smale to larger classes of mappings and cones with possibly empty interiors.

2 - A characterization of Efficiency in Multiple Continuous-Time Programming Problem with Constraints
Gabriel Ruiz-Garzón, Rafaela Osuna-Gómez, Antonio Rufián-Lizana, Beatriz Hernández-Jiménez

In this work, we introduce a new concept of generalized invexity for continuous-time programming problems, namely, the KKT-pseudoinvexity-II. We prove that this new concept is a necessary and sufficient condition for a vector Karush-Kuhn-Tucker solution to be an efficient solution for a multiobjective continuous-time programming problem. Duality results for Mond-Weir type dual problems are obtained, using KKT-pseudoinvexity-II. This work gives an unified point of view for optimality results in mathematical programming or control or variational inequalities problems.

3 - On a Proper -Subdifferential for Vector Mappings. Chain Rules.
Lidia Huerga, César Gutiérrez, Vicente Novo, Lionel Thibault

The most known proper -subdifferentials for vector mappings are defined in terms of approximate proper efficiency concepts of vector optimization in which the error is quantified by a unique vector q and a nonnegative scalar . By means of these concepts, one can obtain sets of approximate proper efficient solutions too big, with points as far as one wants from the efficient set, even for simple problems. Consequently, the -subdifferentials defined through these notions are not suitable for dealing with minimizing sequences.

Here we present a proper -subdifferential for vector mappings defined by means of a recent notion of approximate proper efficiency in the sense of Benson, in which the error is quantified by a set C instead of a vector. For suitable C, the Painlevé-Kuratowski upper limit of these sets of approximate proper solutions is included in the efficient set. Thus, the -subdifferential given by these approximate proper solutions receives this good limit behavior and, because of that, extends and improves the most important proper -subdifferentials introduced in the literature.

Also, we derive exact chain rules for this proper -subdifferential by using a regularity condition and a strong -subdifferential. In particular, we state chain rules when one of the mappings is linear, obtaining

formulations easier to handle in the finite dimensional case with the Pareto order.

■ TD-28
Tuesday, 14:30-16:00 - John Anderson JA3.26, Level 3

Train Timetabling, patient timetabling

Stream: Timetabling
Invited session
Chair: *Pieter Vansteenwegen*

1 - Extending Periodic Event Scheduling by Decisional Flow Transportation Networks
Peter Großmann, Jens Opitz, Reyk Weiß, Michael Kümmling

Automatically calculating periodic time tables in public railway transport systems is an NP-complete problem – namely the Periodic Event Scheduling Problem (PESP). The original model is restricted to basic periodic timetabling. Extending the model by decisional transport networks with flows induces new possibilities in the timetabling and planning process. Subsequently, the given flexibility results in a generic model extension of PESP that can be applied in subsets of the timetabling process. We successfully utilize this approach for distinct chain paths, duplicated chain paths and non-connected flow graphs that represent integration of routing and timetabling, planning of periodic rail freight train paths and track allocation, respectively. Furthermore, we encode this generic model into a binary propositional formula and use several techniques like SAT solving and MaxSAT to calculate and optimize these instances. Computational results and real-world usage suggest a promising perspective for further scientific research.

2 - Approaches to Modeling Train Scheduling Problems as Job-Shop Problems with Blocking Constraints
Julia Lange

The motivation to tackle job-shop problems with blocking constraints is the necessity to schedule all kinds of rail vehicles in real-world networks with increasing complexity and size. For more than four decades the idea to interpret single-track train scheduling problems as job-shop problems has been applied to find feasible, near-optimal solutions, since the underlying combinatorial optimization problem is known to be NP-complete. Trains are to be scheduled according to given routes in networks consisting of single-tracks, sidings and stations with predefined entry and desired leaving times. In order to increase planning certainty in adjacent railway networks the optimization criterion is the minimization of total tardiness of all trains. The presented IP-formulations additionally include blocking restrictions, which refer to a train blocking a track section until the succeeding section on its route is free to travel. Two approaches to transform a railway network to machines differentiated by the inclusion of platforming flexibility in stations are applied. Furthermore modeling alternatives with decision variables defining precedence relations between operations on one hand and assigning operations to order positions on machines on the other hand are set up and discussed. Altogether four different optimization programs are tested on randomly generated instances and compared by means of total tardiness values and computation time.

3 - Evaluation of High-Speed Train Operation Adjustment Scheme based on Train Operation Conflict Resolution
Wen Chao, Tao Siyu

Take the minimum cost of conflict resolution as the reference, a method of train operation adjustment scheme quality evaluation combines 3 modules named the status of conflicting trains, train operation conflict prediction model and cost of conflict resolution is discussed. This paper proposes an evaluation method and a system of train operation adjustment scheme based on calculation of train operation conflicts resolution costs which combines characteristic value of conflict trains, conflict prediction and conflict resolutions. The scheme with the minimum conflicts resolution cost has the highest quality. There are two issues need to be dealt with during train operation conflicts resolution, that is running sequence of conflict trains and the amount of time shift of conflict trains. The procedure of conflicts resolution proposed in this paper can be divided into two steps: firstly, determine the reasonable train running shift by calculating the time cost of conflicts resolution,

and then calculate the conflict resolution cost for each resolution program while after-effects of conflict resolution of train operation is the evaluation criteria of the program. That is considering the rationality of conflict resolution scheme for high-speed rail from a global perspective and finally selecting a reasonable scheme.

4 - A Column Generation Approach for the Elective Surgery Scheduling Problem with both Known and Anticipated Patients

Troels Martin Range, Dawid Kozlowski, Niels Christian Petersen

Reducing the size of waiting lists is a key political issue for hospitals. However, if the waiting lists are short then at the time of planning not all patients are known, and some patients who need treatment within the planning period may arrive after the construction of the schedule. These unknown — but anticipated — patients need to be taken into consideration in the planning process. We include these patients as categories of patients and estimate an arrival process for each category.

We present a set partitioning based formulation for assigning a mix of known patients and non-arrived patients to days of surgery, where the aim is to minimize the expected number of patients who cannot be treated within their due dates. Each column corresponds to a resource-feasible schedule for a given day and we use a column generation approach identifying such resource-feasible schedules. A resource feasible schedule may include surgeries of both known patients and tentative surgeries of patients from specific categories. The allocation of expected arrivals to surgeries include a set of temporal constraints e.g. an arriving patient cannot have surgery before the arrival, and (s)he has to be treated within the deadline of the category. We derive valid inequalities linking the expected number of patients for whom we cannot meet the temporal requirements with the number of tentative surgeries each day. Finally we present a preliminary computational study of the approach.

■ TD-29

Tuesday, 14:30-16:00 - John Anderson JA4.12, Level 4

OR Modelling in Entrepreneurship and Technology Transfer

Stream: Emerging Applications of OR in Economics
Invited session
Chair: *Susan Howick*
Chair: *Bernd Wurth*

1 - Multi-generation technology diffusion: Lessons learned from an agent-based simulation using real-world data

Markus Günther, Christian Stummer

Agent-based innovation diffusion models typically assume just two technology generations (i.e., an existing one and a new one). Thus, they do not differentiate between customers who have adopted the preceding technology generation and customers who may have skipped one or even more generations. Our model extends this paradigm by considering several (succeeding) technology generations. Each comes with products that advance existing features and/or introduces new features. Customers may then opt for substituting their current products by one from the new generation, for postponing the adoption decision until more information becomes available, or for entirely leapfrogging the new technology. Apparently, uncertainty is reduced for customers who are familiar with the functionality of at least some features. Customers who have skipped previous generations therefore may be more sceptical, but their value added will also be higher when switching to the new technology. Accordingly, we can observe not only the (usual) effects on innovation diffusion caused by word-of-mouth and marketing measures, but also effects that can be attributed to consumers' personal experiences. Furthermore, we take the influence of social norms into account and, to this end, have constructed a social network that reflects spatial, cognitive, and social proximity between customers. The applicability of our approach, insights and challenges are demonstrated by means of a sample case based on real-world data.

2 - Exploring the Dynamic Interplay between Entrepreneurial Universities and Their Ecosystem: A Hybrid Simulation Framework

Bernd Wurth, Susan Howick, Niall MacKenzie

Universities play an important role in the knowledge economy and entrepreneurship. In addition, an innovation ecosystem highly benefits from knowledge exchange activities by universities. However, the dynamics of such activities are yet to be investigated. The impact of such activities on both the university and the ecosystem has previously been investigated separately. System dynamics (SD) and agent-based modelling (ABM) are introduced as potential modelling approaches to address this issue. Our analysis shows that neither SD nor ABM can properly fill the gap based on insights from the existing body of literature. We propose a hybrid simulation that uses an integrated SD/ABM approach in which universities are represented as SD modules that shape the environment for the innovation ecosystem, represented as a set of agents. The SD feedback structure acknowledges and reflects the consequences of entrepreneurial activities for and the influence of the ecosystem on the university. As a result, this framework allows for the examination of interplays between the two. Extensions to this framework are highlighted to illustrate its usefulness to other problems that go beyond the field of academic entrepreneurship and innovation ecosystems.

■ TD-30

Tuesday, 14:30-16:00 - John Anderson JA5.02, Level 5

Networks Optimization & Simulation

Stream: Simulation and Optimization
Invited session
Chair: *Dante Gama Dessavre*

1 - Solving the DCVRP with a hybrid methodology combining Ant Colony Optimisation with Constraint Programming

Negar ZakeriNejad, Daniel Riera

Combinatorial Optimization Problems (COPs) have been studied for long. Many techniques and methodologies have been developed to solve them or at least to find acceptable solutions. A number of approaches raise from different fields, mainly operations research, artificial intelligence or applied mathematics. Although the state-of-the-art solutions for a given specific COP are usually very good, they lack the flexibility to easily adapt to variations of the same problem. This happens even more in solutions based on meta-heuristics, since they do not explicitly contain the model of the problem. A change normally implies re-tuning the parameters to fit the new problem. Thus, for instance, given a Capacitated Vehicle Routing Problem (CVRP), extremely good quick solutions are found with meta-heuristics. But the inclusion of a new temporal constraint (moving to a CVRP with Time Windows), implies solving a completely different problem which will require re-tuning all the parameters. In this paper, we provide the initial steps of a flexible hybrid methodology which combines Ant Colony Optimization (ACO) and Constraint Programming (CP), to quickly adapt to changing COPs. We separate the search part (driven by ACO) and the model of the problem (included in the CP part) to take advantage of their best attributes. Here we show the results of initially applying the methodology to the CVRP and move to a Distance-constrained CVRP by adding a new constraint.

2 - Multi-Event Resilience Optimization Formulations

Dante Gama Dessavre, Jose Emmanuel Ramirez-Marquez

System resilience refers to its ability to cope with adversities and be restored back to a pre-disruption state. Resilience is a global concept that encompasses:

1. Reliability - Refers to the time before a disruption affects a system.

2. Vulnerability- Refers to the time that the system is being affected by a disruption and its performance is being diminished as a result.

3. Restorability/Recoverability - Refers to the time where restoration actions are performed in the system as a response to the diminished performance and the system recovers to a new performance level.

The behavior of the system regarding all the components represents the adaptive capacity it has against disruptions. Being able to compare the resilience achieved when evaluating different system modifications can enable better decision making, since priorities regarding what components of resilience are more important differs between systems.

A considerable amount of research has been done to understand the effects of disruptions in system resilience, but mostly focused on metrics that measure the effects of single events at a time. This work presents new multi-event resilience optimization formulations that can enable finding solutions that represent an adequate balance of parameters being optimized and can serve for different decision and systems resilience comparison. The formulations are exemplified with a graph theoretical problem.

3 - Estimating Performance in a Mobile Fulfillment System

Tim Lamballais Tessensohn

This study aims at modeling and analyzing a new kind of material handling systems: mobile fulfillment systems. A mobile fulfillment system is an automated storage system where robots carry pods with products to the picker. As inventory is mobile, the system can automatically sort the inventory and adapt to fluctuating demand, keeping the most popular products close to the pickers. Mobile fulfillment systems are especially suited for E-commerce warehouses with large inventories of small products where demand fluctuates. The system is modeled using semi-open queueing networks that incorporate both multi-line orders and storage zoning. The queueing networks can accurately estimate maximum order throughput, average order cycle time, work station utilization and robot utilization. These networks can be used to optimize the warehouse layout by evaluating maximum order throughput for different length-width ratios of the storage area, by showing the effect of changing the placement of work stations and by quantifying the effect of storage zoning. The main contributions of this work are that it is one of the first to model these systems and that it includes accurate driving behavior of robots and multi-line orders.

■ TD-31

Tuesday, 14:30-16:00 - John Anderson JA5.04, Level 5

Multiobjective Optimization in Network Problems

Stream: Multiobjective Optimization: Modelling and Algorithms
Invited session
Chair: *José Santos*

1 - Compressed Data Structures for the Biobjective 0,1-Knapsack Problem

Pedro Correia, *Luis Paquete*, *José Rui Figueira*

A major drawback of implicit enumeration algorithms for multiobjective combinatorial optimization problems is the large usage of memory resources that is required to store the set of potential solutions during the search process. In this work, we introduce several techniques and data structures that allow to compress a set of solutions during the run of an implicit enumeration algorithm for the particular case of the biobjective 0,1-knapsack problem. Particular emphasis is given on understanding the trade-off between memory usage and computation time, both from a theoretical and practical point of view. The experimental results indicate that some of these techniques allow to have a high compression ratio with very small computational time overhead.

2 - The Multi-objective Travelling Salesman Problem

André Oliveira, *José Santos*

The travelling salesman problem (TSP) is a classic combinatorial optimization problem that has been studied for more than 100 years. Its simple description and its plentiful applications in several areas has allowed it to remain a very productive and up-to-date research topic.

This work focuses on the multi-objective variant of the TSP (MOTSP), which allows to handle problems in presence of conflicting criteria simultaneously. We propose constructive heuristics for the MOTSP on general graphs. A computational study is also presented.

3 - Speed-up Techniques for the Multi-objective Shortest Path Problem

Vitor Freitas, *José Santos*

The shortest path problem (SPP) is a well-studied combinatorial optimization problem. Its wide range of application in real life and the existence of efficient algorithms to solve it has been contributed to attract the attention of researchers on variants of this problem and kept it a very productive and up-to-date research topic.

The SPP has a clear application in Geographic Information Systems (GIS) where it is intended to find the shortest route on several queries of location pairs in a huge network. As all the queries are performed in the same network, several techniques have been proposed to speed up shortest path routing by first preprocessing the data in the network.

In real life, most optimization problems have in nature several objectives to be optimized simultaneously. This is the case of the SPP which leads us to the variant known as the multi-objective SPP (MOSPP). It is a NP-hard problem and it has been studied since the seventies.

This work is focused on speed-up techniques for the MOSPP. The procedures are described and exemplified. A computational study is also presented using real data of the national network.

4 - Multi-criteria Optimization in the Indoor Location and Tracking Problem

José Santos

The indoor location problem consists of the location of an object or person inside a building. Due to the attenuation of satellite signal strength produced by the building, GPS cannot be used to solve the problem. Instead of that, it is used other sensory information collected by mobile devices like the relative received signal strength in a wireless environment. The more common techniques used are empirical method (as the k-nearest neighbour) and mathematical modelling (for instance, trilateration, Bayesian statistical analysis and Kalman filtering).

In this work, a new formulation using multi-objective optimization is discussed. Some algorithms based on this model are presented and a computational study in a real scenario is reported.

■ TD-32

Tuesday, 14:30-16:00 - John Anderson JA5.05, Level 5

AHP/ANP 08

Stream: Analytic Hierarchy/Network Process
Invited session
Chair: *Terezie Bartuskova*

1 - Complex Technology Adoption in Complicated and Multidimensional Organizations

Majid FathiZahraei, *Azita Asadi*, *Govindan Marthandan*, *Murali Raman*

Living with risk increase human-beings vulnerability in planet during the last decades, and made managers concern about reduce the Disaster Management risks. New generation technology, especially in the field of Information System (IS) by ability of combining attribute and spatial data like Geographic Information System (GIS), support managers to reduce risk. Multidimensional aspects of the disaster in terms of type and condition, alongside the complexity of GIS leads to increase sophistication of GIS adoption in the Disaster Management Organisation. Ability of AHP & ANP methods as the methods in the field of Multiple Criteria Decision Making (MCDM) in combining tangible and intangible data, give the opportunity to researchers to analyse a huge and rough data. According to Task Technology Fit, technology must be utilized and fit by user tasks; In this regard, the current study investigates capability of GIS and fitness of this system in different phases of Disaster Management by applying ANP method. The results figured out that the priority of GIS capability is varied in Disaster Management phases. In addition, "Aggregation Method' as a new approach to solve Limit Matrix limitation of ANP method is introduced.

2 - Evaluation of Multicriteria Methods

Chergui Zhor, *Moncef Abbas*

E.Triantaphyllou, during years of joint study and research, has devoted himself to the development of many tests based mainly on some mathematical properties that appear centrally in the famous theorem of Arrow. This reflection seems to be logical, nevertheless, it met a severe criticism from B.Roy. In practice, Judging a multi-criteria

method on mathematical aspects such as the independence of irrelevant alternative and the transitivity can lose the most non-expert users in the field of multicriteria decision. In reality, we should always attract their attention to the fact that the non-verification of certain mathematical properties do not necessarily accuse the reliability of the method. However they must be informed of the limitations following the use of each method. Frequently the non-verification of these two properties is an inevitable consequence of the ranking process characterizing the method, such as, Electre, Promethée, AHP,... etc. To this end, it would be better to evaluate the performance of the method according to the practical results rather than on theoretical aspects. In unanimity of methods (ie when several methods define exactly the same good solution), the problem of the definition of the best alternative A* is practically solved. otherwise, we must ask ourselves which one of the solutions obtained by the different methods is the right solution. On this basis a new test is developed. It allows to choose the best solution among several good solutions.

3 - Analysing a Case of Vendor Selection Model for Indian Industries of all Categories through Known Procedures of AHP
Ravindra Mohan

The main objective of this paper is to capture both the subjective and the objective evaluation measures in order to solve vendor selection especially when different organizations have different combinations of qualitative and quantitative criteria and sub-criteria in Indian manufacturing industries like computer hardware, automobile,process and machine tool manufacturing industries. This paper provides the basic guidelines to develop the vendor selection model based on AHP. Developing AHP model by identifying the selection criteria and determination of the most important priorities is briefly defined through this paper. This paper also provides basic ways to calculate the weights of each criterion and enable decision makers to examine the strengths and weaknesses of the vendors' selection by comparing them with respect to appropriate criteria and sub- criteria

4 - Application of AHP Tool for Developing Decision-making Framework to Choose Fruit and Vegetable Waste Processing Method for Industries
Amit Tare, Rahi Jain

India's fruit and vegetable (F&V) processing industry waste management is an important issue as industries loose significant revenue owing to nil/inefficient/low value processing methods. The lack of any multi-criteria decision making framework for comparing processing technologies (PTs) to produce multiple and/or different products is an important limitation to maximize economic benefit from waste. This study focuses on developing a multi-criteria decision making framework using Analytic Hierarchy Process (AHP) for F&V waste PTs. The two step framework was designed namely, PTs Selection with two sub-steps namely identifying PTs alternatives and Alternatives selection for comparison and AHP based PTs ranking. DM, criteria, criteria values and relative criteria weights data was based on literature review and anecdotal information from experts. Two F&V waste PTs namely vermicomposting (V) and Transesterification (V) were selected as sample technology for this study. They were compared with 7selected criteria with 2 level grouping. Vermicomposting were most appropriate F&V waste PTs. The sensitivity analysis performed by eliminating one criterion at a time showed that "Technology Cost' was the most sensitive criterion for F&V waste PTs. An AHP based framework was developed with flexibility to have user defined alternatives, criteria and criteria weightages DM selection.

5 - Application of AHP in SWOT Matrix Compilation
Terezie Bartuskova

One of the main tasks of the top managers is setting the strategy which allows the company to succeed on the market. In the process of strategy setting, managers must identify the external and internal environment of the company, which influence the future strategy. For this purpose several analyses are used. SWOT analysis is one of the most often used analyses, which utilize the results from previous external and internal analyses. Despite SWOT analysis being very popular, it has its weaknesses. One is the lack of methodology in the evaluation of partial analyses results. It is not only important to identify all factors of external and internal environment, but it is necessary to evaluate the impact of each factor. Analytical hierarchy process (AHP) can be applied to evaluate the significance of every factor and this method can help to decide whether the factor is strength or weakness of the company (in case of internal environment analysis), or whether it is opportunity or threat (in the case of external analysis). The aim of the paper is to introduce the methodology of using AHP method for SWOT matrix

compilation. In the paper the proposed methodology will be applied in order to compile SWOT matrix of a selected company.

■ TD-33
Tuesday, 14:30-16:00 - John Anderson JA5.06, Level 5

Knowledge in Organizations Concepts

Stream: Knowledge in Organizations
Invited session
Chair: *A. D. Amar*

1 - What is 'capability' in capability-based acquisition?
Thomas Ekstrom

The Swedish Defence Procurement Agency (DPA) is in the process of changing from procurement of equipment to acquisition of performance, e.g. availability and/or capability, and from procurement through competition to novel forms of acquisition through, e.g., partnering. In addition, the Swedish Armed Forces and the DPA are exchanging and transferring resources, roles and responsibilities, in order to enhance overall effectiveness and efficiency. Based on a literature review, this paper discusses the concept of capability in the context of defence acquisition. What 'capability' will be acquired by the DPA? What 'capability', e.g. knowledge, is required within the Swedish Armed Forces Head Quarters and the DPA in order to acquire 'capability'? How is this knowledge (capability) acquired and maintained? In short; what is capability in the context of public procurement in general, and in the context of defence acquisition in particular.

2 - Resource-Based Perspective in Knowledge Management: How to Apply for Success in Organizations
A. D. Amar, Rocco Russomano

This paper covers resource-based perspective in knowledge management in organizations. We break down the theory, its application, the positives and negatives that come from managing with it, and the criticisms that question how to gauge the efficiency of the theory. First, from the current research and applicable theory, we examine the fundamentals and key elements of the resource-based perspective. We, next, identify different types of knowledge-based resources and the processes being used to manage knowledge. Then, we look at the empirical studies done to validate that managing from a resource based perspective leads to success. We also discuss how different industries utilize tangible human resources and intangible resources such as the reputation. The paper closes with a review of the different critiques and criticisms that question the completeness and practicality of the resource-based view. Directions for further research are provided.

■ TD-34
Tuesday, 14:30-16:00 - John Anderson JA5.07, Level 5

Emerging Applications on the Cloud 1

Stream: Emerging OR Applications on Cloud Computing
Invited session
Chair: *Merve Unuvar*

1 - Integer Programming Model for Auto Scaling Virtual Machines in to Multiple Availability Zones
Merve Unuvar

Elasticity is essential for Cloud Computing. It is achieved through automatically scaling virtual instances that are hosted on the Cloud as the usage of these virtual instances increases. The decision on when to scale is usually determined by the user-defined policies. However, the decision on where to scale the virtual instances is not stated by the user hence left to the Cloud provider.

With increasing demand for Cloud Computing, availability zones play crucial role to meet the elasticity requirements and allow auto scaling to multiple availability zones. An availability zone is a data center that is physically isolated from other availability zones. Cloud providers offer several of such availability zones in various geographies. For any Cloud provider, availability zones are not identical - their hardware

infrastructure type, version of management stack, and load characteristics differ. As a result, services offered by different availability zones will vary. In this work, we are proposing an integer-programming model for automatically scaling virtual instances into multiple availability zones by considering various properties of the zones as well as user constraints such as budget, quality of service, and reliability. We then solve the problem with branch and bound algorithm and Cplex Solver Package.

2 - Exploring the Social Network-based Feasibility of Cloud Services for Travel Time Reliability with a Focus on Aging People
Ayberk Kocatepe, Eren Ozguven, Javier Lores, Javier Lores

A significant task of decision makers involved in transportation logistics is planning for and dealing with the highly stochastic traffic conditions. To accomplish this, cloud-based logistics can be utilized as a vital tool to reduce the impacts of traffic congestion improving the reliability of traffic operations. This problem becomes even more challenging when aging populations are considered since any extra time incurred for the aging can be especially dangerous in light of health and other safety concerns. This paper carefully describes the steps needed to create an aging-focused logical architecture for real-time cloud-based transportation logistics with an emphasis on the sustainability/reliability of the transportation networks. This architecture will be supported by the Twitter data in order to facilitate advanced data analytics, identify the incident geo-locations, and compute alternative routes. First, a transportation cloud is built in order to store the Twitter data, facilitate the back-end data analytics and allow for scalability. Next, a real-time road closure geo-location analytics is developed by leveraging machine learning techniques and applying them on the Twitter data. Finally, a dynamic shortest path-based route navigation technology is developed based on the geo-located road closures and real-time traffic information. This architecture can successfully serve to develop aging-focused travel time reliability measures for better traffic operations.

3 - Cloud Powered Brewing: The Impact of Cloud Computing in Operational Research
Simon Taylor

There are many software applications used in OR that can be computationally demanding. For example, to analyse the effectiveness of a manufacturing system we might use process simulation software to build and then simulate models of the system under different experimental scenarios and parameter values. Experimentation (and testing) can take a long time as simulation experimentation can consist of many independent simulation runs (and replications). It is reasonable to assume that if these runs could be executed in parallel then the time taken for experimentation might be significantly reduced. As part of the I4MS ICT for Manufacturing SMEs initiative launched in FP7, the Cloud-based Simulation platform for Manufacturing and Engineering (CloudSME) project (www.cloudsme.eu) has brought together a range of technology providers, software developers and end users across Europe with the aim of developing new "cloud powered' applications. This presentation will give a brief background to cloud computing and the CloudSME Simulation Platform and project. It will focus on the technology supply chain needed to deliver low-cost process simulation to the Craft Brewery sector and reflect on other potential benefits from this successful collaboration between technology providers, OR specialists and industrial end users. The presentation will conclude with reflections on how critical it is for OR to embrace new technologies, especially with regard to Big Data Analytics.

4 - Deployment of Multi-tier Software Services in Clouds — a Branch-and-Price Approach
Anders N. Gullhav, Bjørn Nygreen

In the service provision, a provider of cloud software services has to make decisions about the placement of the virtual machines of the services. A virtual machine runs a single tier of the multi-tier services, and the provider has to decide the number of virtual machines running each tier, such that the quality of service is in accordance with the requirements of the clients. The placement is modelled as a mapping between the virtual machines and the physical nodes operated by the provider himself. In an extension, we allow placement in public clouds in addition to the private cloud of the provider. The problems can be formulated as a mixed integer program (MIP). However, we show that a reformulation solved using branch-and-price performs much better than a direct MIP formulation. In the branch-and-price approach new node packings is generated by solving a subproblem. We have tested both heuristic and exact methods for solving this subproblem, and present computational results when comparing the different approaches.

■ TD-35
Tuesday, 14:30-16:00 - Colville C429, Level 4

DEA applications: logistics and transportation

Stream: DEA and Performance Measurement
Invited session
Chair: *Erwin Lin*

1 - On the Way to Achieve a Targeted Logistics Performance
Sule Onsel Ekici, Özgür Kabak, Fusun Ulengin

A country's ability to trade globally depends basically on the traders' access to efficient logistics networks. The efficiency of logistics networks, in its turn, depends on government services, investments, and policies. Building infrastructure, developing a regulatory regime for transport services, and designing and implementing efficient customs clearance procedures are all areas where governments play an important role. One of the measures for logistics performance at national level is the Logistics Performance Index (LPI). LPI is composed of six indicators namely customs, infrastructure, service quality, timeliness, international shipments, and tracking and tracing. This study argues that there is a close relationship between the global competitiveness and the logistics efficiency of a country and it analyzes the validity of these relation using artificial neural network (ANN) and cumulative belief degrees (CBD) approach. For this purpose; initially, a workshop is conducted to find the World Economic Forum's competitiveness indicators that may have an impact to each of LPI indicators. Subsequently, the relationship between the competitiveness indicators and LPI indicators are analyzed using ANN where the LPI indicators are represented by CBDs. As a case study, the methodology is used to analyze Turkey's logistics performance and to develop the basic strategies to be adopted by the government to achieve a targeted LPI level of the country

2 - Distribution Centralization and the Efficiency in IT-Enable Supply Chain: A Firm-Level Empirical Research with Non-Discretionary DEA Methods in Retailing Industry
Liu Jiawen, Zhang Jinlong, Yeming Gong

While some research argues that distribution centralization can improve cost performance, other contends that the impact of centralized distribution is negative as it reduces agility performance, and integrated IS capability negatively moderates the relationship between distribution centralization and organizational performance. Using a sample of 125 organizations in retailing industry, we develop a non-discretionary two-stage data envelopment analysis model, allowing IS capability as inter-temporal effects in efficiency measuring, to study the relationships between facility inputs of distribution centralization and organizational performance, integrated IS capability and operational efficiency in retailing. We present country–level, size–level and product–level profiles in supply chain strategy, IT and operational efficiency, and provide a new framework to understand the role of centralized distribution in supply chain strategy.

3 - Evaluating performance of rail transport by bootstrap data envelopment analysis
Erwin Lin

Rail transport has long played an important role in the economic development for a country and thus enhancement of its operating efficiency is a crucial issue to be sustainable in a competitive context. Many researchers have endeavored to rail transport performance evaluation by DEA in the past several decades. However, at least two drawbacks existed in the previous studies. First of all, they generally ignored the important input factors. Secondly, DEA has been criticized for not taking into account statistical noise and lacking any hypothesis testing. To rectify, this study selects 8 input variables, and applies Bootstrap DEA (BDEA) method to estimate the efficiency and confidence intervals for 19 European rail companies in 2011. The empirical results indicate that using DEA method 15 railways are evaluated as efficient and the average technical efficiency is 0.932 based on variable returns to scale technology, this is because of choosing eight input variables. While using BDEA, none of 19 railways is evaluated as efficient and the average

efficiency is 0.817, implying that the DEA method overestimates the efficiencies of railways under study. The results also indicate that the 95% confidence interval of the efficiency estimated by BDEA, from which one can obtain the outputs that each railway should expand so as to be efficient. Finally, based on the results some strategies for improving railways' performance and possible avenues of future research are proposed.

■ TD-36

Tuesday, 14:30-16:00 - Colville C430, Level 4

Issues in Education and Social Policy

Stream: Education Policy
Invited session
Chair: *Emel Savku*

1 - The Effectiveness of Driver Education and Information Programs in the State of Nevada

Alexander Paz, David Copeland, Pankaj Maheshwari, Kris Gunawan, Hanns de la Fuente

According to National Highway Traffic Safety Administration, pedestrian and driver crashes are increasing at an alarming rate due to technological advancements and human errors. The objectives of this research were i) to examine the quality of Nevada's driver education by evaluating the effectiveness of its programs, and ii) to provide recommendations to improve driving education in Nevada based on the results from this study. Two different surveys were conducted in Clark County, Southern Nevada. The corresponding recommendations were organized into seven major categories: (i) lack of rigor of online driver education, (ii) interactive learning and technology, (iii) follow-up exams, (iv) practice/training at home, (v) collecting information about crashes, (vi) pedestrians, and (vii) additional emphasis. Finally, due to the dangers of driving distractions (texting and calling on the cellphone) and impairments (driving under the influence of alcohol or drugs), more emphasis on these topics — as well as more public announcements through billboards, television commercials, and magazines — can help to constantly remind drivers about having good driving habits.

2 - A new framework of operation research and learning path recommendation for next-generation of e-learning services

Nabil Belacel, Guillaume Durand

This work presents the contribution of operational research to education and more particularly to learning design with the implementation of a learning path recommendation system for the next generation of e-learning services. A learning design recommendation system would help learners get appropriate learning objects through an efficient learning path during their self-directed learning journey. The quantity of learning objects available is constantly growing, and millions are now available online. Therefore designing a learning path can be a tedious task that could be eased with the help of software capacities. Moreover, most of the existing recommender solutions proposed by different research communities including educational data mining are not suitable for the very large repositories of learning objects and does not take into account the complexity of the problem in their optimization process. To alleviate this difficulty, we proposed a general approach based on graph theory and mathematical programming to optimize the learning path discovery. The first step of the approach consists in reducing the search space by iteratively building sub-graphs as a succession of cliques form the targeting competencies to competencies reachable by the learner. In a second step, our mathematical model takes into account the prerequisite and gained competencies as constraints and the total competencies needed to reach the learning goal as the objective function to optimize.

■ TD-37

Tuesday, 14:30-16:00 - Colville C411, Level 4

OR for Development and Developing Countries 2

Stream: OR for Development and Developing Coun-
tries
Invited session
Chair: *Laura Lotero*
Chair: *Elise del Rosario*
Chair: *Andres Felipe Osorio*

1 - Before and After Trade Liberalization. Case of Total Factor Productivity in the Colombian Manufacturing Industry

Raul Chamorro-Narvaez

In this paper, we measure and analyze total factor productivity —TFP-growth in the Colombian manufacturing industry over the period 1985-2010. From the early 1990s, several policy actions aiming at increase trade openness of the Colombian economy took place. Taking this into account, in this article we analyze the performance of several subsectors of the Colombian manufacturing industry before and after trade liberalization. TFP growth is measured by using Harberger's Two-Deflator Method. Compared with traditional methods, it is robust, relatively easy to use, and needs a reasonable amount of data for calculations that is easy to handle. Our results show that most of the subsectors analyzed had positive TFP growth rates during the period 1990-2010, which corresponds to a period of more openness of the Colombian economy, compared to eight out of twenty subsectors with negative TFP growth rates in the period before trade liberalization (1985-1990). Our results suggest a positive effect of trade liberalization of the economy on TFP of Colombian manufacturing industry.

2 - The Role of OR/MS within the Strategic Decision-making of Colombian Organizations: An Observational Study

Julián Benavides, Felipe Henao, Cristian Trejos

The OR Society in UK defines OR/MS as "the discipline of applying advanced analytical methods to help make better decisions'. OR/MS provides a wide range of tools that have been proved to be effective in facilitating decision-making at all levels, from the operational to the strategic level, and for different types of organizations. With this study we aim to explore to what extent Colombian organizations are actually taking advantage of the developments made in the field. We seek to explore if OR/MS plays a key role in informing strategic decision-making in some well-known Colombian companies. To this end, we launched an online survey to collect information about the methodologies and tools most commonly used by top managers, and the types of decision problems they aim to address with them. Second, we applied in-depth semi-structured interviews to find out, in more detail, the practices and processes that local companies follow when making strategic decisions. Our results show that managers hardly know what OR/MS is good for and what methods are available. Results also suggest that few tools are employed in practice and instead companies develop their own procedures and tools. Therefore, this could be a wake up call to university professors, as well as for those in the recently formed Colombian OR society (ASOCIO), to think of strategies that could make OR/MS go beyond the classroom and make a real impact in all types of organizations.

3 - Development of a Mathematical Model for Uninterrupted Supply of Electricity in Developing Countries

Olabode Adewoye

Electricity supply in most developing countries is characterized by frequent failures, low generation and inadequate generating plant. The problem is localized to Nigeria. A quadruple electricity market model is developed which was used to generate a set of stationery policy. A continuous semi Markov decision processes which generates the optimum stationery policy provides the solution to the problem.

4 - Time to change the path? Adaptive Water Management using multi-criteria decision making- a case study

Farideh Delavari Edalat, M Reza Abdi

Adaptive Water Management (AWM) could provide a sustainable route to address the existing complex problems of urban water management through the future. This paper highlights that despite many contributions to the AWM debate in the recent years, still there is a lack of clarity surrounding the concept of AWM, and also there is no clear agreement on the measurements for reaching adaptability in AWM. This research is intended evaluate the extent of adaptability in water management using the three main AWM characteristics of polycentric

governance, Organisational flexibility and public participation as the performance measurements. The paper is intended to compare AWM and Water Supply Management (WSM), as two possible alternatives. In order to compare AWM with WSM in Greater Tehran, a hierarchy structure was designed to show the attitude towards these two different water approaches regarding water governance, institutional process and public participation. The data collection was processed by predetermined semi-structured interviews from professionals who were knowledgeable in water industry based on conceptual framework that played a major role in data collection. A multi criteria decision making model using Analytical Hieratical Process (AHP) is proposed and the participants' responses were transformed and weighted by AHP using pair-wise comparison for further analysis of sub-criteria (characteristics) of AWM and WSM.

■ TD-38

Tuesday, 14:30-16:00 - Colville C410, Level 4

Quality and Performance Measurement in Humanitarian Relief Chains 2

Stream: Quality and Performance Measurement in Humanitarian Relief Chains
Invited session

Chair: *Sadia Samar Ali*

■ TD-39

Tuesday, 14:30-16:00 - Colville C405, Level 4

Knowledge Management & Group Decision Making

Stream: Decision Support Systems
Invited session

Chair: *Pascale Zaraté*

1 - Towards A Pecking Order Theory of Enterprise Knowledge Management
Daniel OLeary

There are limited theories of how knowledge is captured, accessed, used and shared by individuals in enterprises. Further, few theories provide operational predictions. For example, would we expect individuals within an enterprise to ask a person for specific knowledge or would we expect them to find it in a repository of documents? This paper develops a theory for knowledge management based on the "pecking order' approach. After establishing the theory, the paper examines previous literature in knowledge management as a basis to substantiate the use of the theory.

2 - A Usage Preferences Ontology for OLAP Systems
Orlando Belo, Eduardo Costa

This paper presents a generic ontological model conceived to represent OLAP system users' preferences. The model was designed according to the most common principles and methods of the Semantic Web, with the goal to improve user experience in OLAP sessions. Ontologies have proven to be an effective mean to represent information systems in many application domains, having the ability to provide a very effective overview of the domain involved, with a high level of abstraction, providing a rich semantics for the models represented, facilitating their interpretation and processing. These are the characteristics that we intended to bring to OLAP systems, especially when we deal with very demanding data querying scenarios. The developed preferences model is supported by three elementary components: the user profile, the multidimensional database schema and preferences. The first component includes the definition and characterization of interests, activities, and user capabilities, which define preferences according to the technique of Golemati et. al. (2007). The second component includes the characterization of the multidimensional database, which supports the preferences about hyper-cubes, dimensions and measures. Finally, the third component includes the representation of the preferences. The ontological model proposed is an evolution from the ones

presented by Chomicki (2003), Kießling (2002), and Köstler Kießling (2002) and Golfarelli and Rizzi (2009).

3 - Quasi-statistical decision and group decision support tools based on geometric mean method for judgement matrices: harmony with arrow's impossibility theorem
Dmitrii Tomashevskii, Tomashevskii Igor L.

What is an ideal decision/group decision support tool? In our opinion, 1) it should be a standard measuring tool, which generates quantitative estimations of alternatives and reliably indicates their errors and 2) it should be free from any rank reversal phenomena and automatically harmonize with Arrow's impossibility theorem, which says that any group decision-making algorithm using preference rankings could be in situations where realistic ranking of alternatives is not possible: in similar situations, the ideal tool should generate only nondeterministic results. We construct the pairwise-comparison-oriented tool that is not "ideal' but conforms to these requirements, and demonstrate its software realization. We begin from the geometric mean method (GMM) widely used in decision-making processes. The original GMM is logically incomplete and has significant drawbacks: its actual errors are unknown and its reliability is doubted by rank reversal phenomena. Moreover, the original GMM group decision-making procedure allows Arrow's paradoxes and other illogical phenomena. We find the actual GMM errors and show that all GMM rank reversal phenomena are eliminated when the GMM errors are taken into account. The GMM decision support tool is composed. In situations where group decision-making based on the original GMM leads to illogical paradoxes, this tool indicates the impossibility to deterministically rank alternatives and performs a probabilistic ranking and analysis.

4 - An Optimal Group Ranking Method based on Maximum Consensus Sequences
Li-Ching Ma

Group ranking problems are commonly found in real-world decision problems. Therefore, determining how to best aid a group-ranking process is important. Most previous studies have minimized the total disagreement among multiple input preferences in order to achieve an overall ranking list; nevertheless, the fact that users might have little or no consensus on the final results was neglected. Instead of achieving an overall ranking list, some research generated only maximum consensus sequences where the group consensus preference could be met. However, maximum consensus sequences are usually fragmented whereas in practice a complete total ranking list is generally more helpful in making decisions. This study aims to propose an optimization model to obtain a final total ranking list based on maximum consensus sequences. A group consensus mining approach was first developed to determine maximum consensus sequences, and then an optimization model subject to maximum consensus sequences was constructed to achieve a total ranking list. Compared to previous methods, the proposed approach is better able to determine maximum consensus sequences without a need for tedious candidate generation processes. It can also produce a total ranking list where most of the decision makers have consensus.

■ TD-41

Tuesday, 14:30-16:00 - Colville C512, Level 5

Non-additive Integration in MCDA II

Stream: Multiple Criteria Decision Aiding
Invited session

Chair: *Brice Mayag*

1 - A characterization of the 2-additive symmetric Choquet integral using trinary alternatives
Brice Mayag

In a context of Multiple Criteria Decision Aid, we present some necessary and sufficient conditions to obtain a symmetric Choquet integral compatible with some preferences on a particular set of alternatives. These axioms are based on the notion of strict cycle and the MOPI conditions.

2 - The WINGS Method — Fundamentals and Review of Applications
Jerzy Michnik

WINGS (Weighted Influence Non-linear Gauge System) has been designed to handle complex problems of interrelated factors. It can be regarded as a link between soft and hard OR because it combines a network similar to a cognitive map with quantitative assessments of system components attributes. The graphical tool used in WINGS facilitates problem structuring and supports learning and comprehension during the decision process. On the other hand, the use of numerical scales enables quantitative evaluations and, in particular, ranking of decision alternatives. The power of WINGS as a decision-supporting tool is illustrated by various examples of applications in such fields as: innovation management, health care organization, public relations (PR), regional government strategy, credit risk assessment.

3 - Axiomatization of the Choquet integral
Mikhail Timonin

We prove a representation theorem for the Choquet integral model. Well-known in decision making under uncertainty, the integral also gained a lot of popularity in multiattribute utility theory (MAUT) due to the tractability of non-additive measures in this context. The model is capable of reflecting various preferential phenomena, such as criteria interaction, which are impossible to reflect in the traditional additive models. In MAUT the preference relation is defined on a heterogeneous product set where elements of the factor sets (criteria sets) are not necessarily comparable with each other. However, making such comparisons in a meaningful way is necessary for the construction of the Choquet integral. We construct the representation, study its uniqueness properties, and look at applications in decision analysis. The crucial difference between our result and previous axiomatizations is that the notions of "comonotonicity" and "constant act" are no longer available in the heterogeneous case. Recall that two acts are called comonotonic if their outcomes have the same ordering. A constant act is plainly an act having the same outcome in every state of the world. Apparently, since criteria sets in our model can be completely disjoint, neither of the notions can be used anymore due to the fact that there does not exist a meaningful built-in order between elements of criteria sets. New axioms and proof techniques must be introduced to deal with this complication.

4 - Nonlinear expert estimates concordance for multiple criteria decision making based on preference learning
Leonid Lyubchyk, Galyna Grinberg

One of the most important problems of decision making theory is multiple criteria comparative assessments and ordering of objects based on expert judgments. The widely practiced approach is the reduction of a set of partial performance indexes, to the generalized one, known as an integral indicator, which should be constructed on the basis of expert preferences. In practice, the commonly used preference function model is a linear convolution of partial performance indexes, where feature weights are given by experts, but it not always adequately representing the actual expert preferences. The developed approach allows considering the problem of multiple criteria nonlinear convolution as a problem of preference function identification based on both feature measurement data and expert estimates of integral indicators and feature weights. Herewith expert estimations of feature weights in linear feature convolution may be considered as a first approximation for nonlinear feature convolution and may be used as a priory information for optimal expert estimations concordance according to the technique proposed in the paper. The proposed generalization of expert estimate concordance idea for the case of nonlinear preference function guaranties on optimal concordance of measurement and expert data, whereas machine learning approach coupled with kernel-based technique ensure the possibility of expert preference function approximation with complex structure.

■ TD-42

Tuesday, 14:30-16:00 - McCance MC301, Level 3

OR in Civil Government 2

Stream: OR in Civil Government
Invited session
Chair: *Vivienne Raven*

1 - Assurance Scoring for High Volume Application Workstreams in Government
James Lofthouse

Assurance Scoring for High volume application workstreams in government Big data and predictive analytics is a rapidly growing field. Every day, companies such as Facebook and Google collect information about us that is used to build models designed to predict our behaviour. Will the customer click on a certain advert if he is presented with it? Will the applicant for credit default on his loan? The knowledge and understanding required to build such complicated models is substantial — not just from a technical point of view, but also because of the importance of business input for framing the question and delivering useful output.

In government there are a number of high volume application areas where outcomes could be improved by these approaches. We have recently undertaken a proof of concept project investigating the use of predictive analytics to score applications on how likely they are to be compliant. In this talk, I outline some of the problem structuring challenges we have encountered to orient a discussion around the importance of the business involvement in analytics projects, and also explain how we assess the performance of probabilistic predictive models.

2 - Dynamic micro-simulation for forecasting Working Age Benefits in the Department for Work; how we have used it to model new benefits such as Universal Credit
Tanya Powell

INFORM (INtegrated FORcasting Model) is a dynamic micro-simulation model used to forecast multiple working age benefits on an individual basis. It was developed to cover a range of 9 out-of-work and disability benefits, benefit combinations, and claimant characteristics. The model has been expanded to incorporate 2 additional benefits, and adapted to make initial forecasts around working hours, families and Universal Credit.

This presentation will cover how the model works, its strengths and weaknesses, how we have adapted it to inform the analysis around Universal Credit, in particular in planning the migration to Universal Credit from the current system.

3 - Rebuilding the National Population Projections system
Amy Large

The National Population Projections for the UK are currently produced by the Office for National Statistics (ONS) every two years. They provide a picture of how the population may develop in future years based on a variety of assumptions about future fertility, mortality and migration. The results are used by government departments to help plan for things like future pension provision, school place requirements and the demand for health services.

The last set of these projections were produced in 2013 using an Excel based system. With the civil service move to Windows 7 in 2014, this system unexpectedly ceased to function. It had been built in the early 1990s by methodological specialists, and little knowledge of how to modify the system remained. The system owners were now left in a difficult position. The next set of population projections had to be produced towards the end of 2015 and there was no extra budget or man-power resource available to dedicate to or commission a new system. The Excel system was also not compatible with new methods being trialled that, if proven to be successful, would be implemented in future sets of projections.

This paper will discuss the approach taken to ensure a robust and flexible system, and how the Population Projections team collaborated with Statistical Computing Branch (SCB) to achieve that objective. The paper will also discuss how SCB are providing a responsive resource to help tackle these kinds of unforeseen issues in ONS.

4 - A New Analytics Model for Balancing Capitalism, Socialism and Bureaucracy
Cathal Brugha

We use nomology to form a new economics management analytics model that is based on balancing: capacity, capability, community, and contribution. We show that capitalism uses a subjective model based on capacity (need), capability (preference), and contribution (value), and re-invests its output in building further capacity. Socialism uses an objective model, which is "post-capitalist' in that it includes a subsequent output to community. Theoretically there should be a balance

between: capitalism, which maximises investment in the corporate sector; socialism, which maximises dividends to households; and managing bureaucracy, which should minimise overheads by government and the financial sector. We use the model to show some unsustainable features today. Between 2007 and 2014 the global debt to GDP ratio rose from 2.0 to 2.8; debt to households dropped from 23% to 20%; and debt by government increased from 23% to 29%. Worse than the imbalance between capitalism and socialism, is that government bureaucracy's failure to manage itself, and the challenges of financial globalisation, despite the capabilities of I.T.-based analytics, will lead to global economic recession and social unrest. We use a parallel nomological model to suggest some solutions, based on balancing: responsibility, transparency, authority, and accountability; and expose some flawed public service theories: Progressive Public Administration (PPA) and New Public Management (NPM).

■ TD-44

Tuesday, 14:30-16:00 - McCance MC319, Level 3

Fuzzy Systems II

Stream: Fuzzy Optimization - Systems, Networks and Applications
Invited session
Chair: *Nihal Erginel*

1 - Conditional Random Field based Intrusion Detection using Sequence Characteristics in Control System Communication
Takashi Onoda

The importance of cyber security has increased with the networked and highly complex structure of computer systems, and the increased value of information. Especially, attention is currently focused on the cyber security of control system. In this paper, we compare Conditional Random Field based intrusion detection with the other probabilistic models based intrusion detection. These methods uses the sequence characteristics of network traffic in the control system communication. The learning of models only utilizes normal data, assuming that there is no prior knowledge on attacks in the system. We applied some probabilistic models to intrusion detection in DARPA data and an experimental control system network, and compared the differences in the performance.

2 - The parameter method for solving fuzzy multi-criteria fractional transportation problem of "bottleneck" type.
Alexandra Tkacenko

The multiple criteria optimization problems with fuzzy parameters and coefficients are the most important in our days, because of their often applications in various managerial decision processes especially at the first, when all most indices features of economic processes are inaccurate. In this paper is presented an interactive solving approach for the multi-objective fractional transportation problem with fuzzy cost coefficients and time minimizing criterion. The approach is based on interval presentation of each cost functions coefficients. By finding of the probabilistic parameter of belonging of coefficient value of objective functions to their variation interval at least for one objective function coefficient, we can iteratively calculate the values of all objective functions coefficients. Thus we reduce the fuzzy type multi-criteria model to one of deterministic type. Next, we will find iteratively the corresponding set of efficient solutions for the multiple criteria transportation model for one fixed value of parameter, according with all time minimizing levels. Thus, reducing the initial model to a stochastic problem type led to solve the last by varying membership parameter values of the intervals. In other words, we have obtained one significant result, that any decision-making situation described by the proposed model can be predicted by its time and cost characteristics. The proposed algorithm has proved to be quite efficient, being tested on several

3 - A Hybrid Artificial Neural Network Approach Based Information Criteria for Credit Scoring
Derya Soydaner, Ozan Kocadağlı

Artificial neural networks (ANNs) are useful tools in terms of providing the efficient solutions for the classification problems in the credit scoring. However, the analysts mostly do not take into account some requirements such as controlling the model complexity, the over/lower-fitting and the selection of learning algorithm during training of traditional ANNs. In order to estimate the robust models, handling these subjects is inevitable. In this study, a hybrid approach is proposed that allows the decision makers to estimate much more efficient models in the nonlinear environments. In this approach, the feedforward ANNs are hybridized by Genetic Algorithms, and then model complexity and overfitting issues are considered by means of the information criteria. In the application section, the proposed procedure is compared with logistic regression and traditional training procedures of ANNs over German credit data set.

4 - Open Vehicle Routing Problem under Fuzzy Used Capacity of Vehicle Constraint
Nihal Erginel, Gamze Tuna

Open vehicle routing problem is a type of vehicle routing problem that the vehicles are not return to the depot. In many study, the routes are defined with minimum total travelling distance objective under vehicle capacity constraint. But, the unused capacity of the vehicles are not considered as a constraint. If the total assigned demand of a vehicle is under certain ratio, the extra cost will occur due to the empty space that is not used capacity of the vehicle. Therefore, used capacity of vehicles are taken into account as a constraint in the model. On the other hand, when the unused capacity ratio is defined as a crisp value, the vehicles has acceptable used capacity are not allowed for routing and some demands cannot be satisfied. So, fuzzy approach is an inevitable tool for solving such problems. In this study, model is handled under fuzzy used capacity ratio constraint for minimizing total travelling distance. Unsatisfied demand should be met in three days. Therefore, the model is solved iteratively for a certain period.

■ TD-45

Tuesday, 14:30-16:00 - Graham Hills GH514 Lecture Theatre

Case Studies in Public Transport

Stream: Optimization of Public Transport
Invited session
Chair: *Steven Harrod*

1 - The Passenger Transport Mode on Chinese High-speed Rail Network
Peng Qiyuan, Yin Yong

Two passenger transportation modes of high-speed railway are proposed, which are the through mode and the transfer mode. Advantages and disadvantages of each mode as well as its operating conditions are analyzed, and the appropriate modes of high-speed railway network, intercity high-speed railway network and mixed high-speed railway network are discussed. For the through mode, as a precondition that the priority of over-line train is higher than that of in-line train, the train diagram of over-line train is studied,and the skylight plan which has the best adaptability with the sunset-departure and sunrise-arrival train is tried to be found. While for the transfer mode, the transfer node plan is designed aiming to ensure passengers to have the maximumdegree of travel choice freedom and the train's linkage plan is discussed by considering two aspects which aretransport capacity matching and train linkage time. Then based on the characteristics of passenger flow, considering both transport enterprise income and passenger generalized travel cost, models for passenger transportation mode choosing are established by constraints of electric multiple unit maintenance distance and passenger flow strength. At last, taking the high-speed railway network as example to verify the simplifying method, the key OD distribution of the whole network is obtained, and the through mode is better for Guangzhou-Taiyuan.

2 - Bus Frequency Optimization under Mixed Traffic Condition for Delhi
Hemant Suman, Nomesh Bolia

The quality of the public bus transport in Delhi is not in accordance with the commuters expectation. A study on major problems with the public bus transport in Delhi has revealed that overcrowding of buses is the top most problem. Further, the study also finds some areas have

more buses than they need and some are totally ignored. As a results, the mode share of public buses is continuously decreasing. In order to provide the adequate level of services to the commuters over the entire bus network of 657 bus routes, a model is developed that will optimize the frequency of buses under mixed traffic and also determine the number of buses on each route. It will provide policy support to the state transport authority in determining the exact number of buses and headways over different time intervals under mixed traffic condition. The new model considerably increases the comfort levels of passengers and consequently can also be a driver for increased mode share of public buses.

3 - Planning the Trial of a Hub-and-Shuttle Public Transport System
Philip Kilby

Off-peak public transport presents many challenges, particularly in servicing the lower-density suburbs that fringe many modern cities. A hub-and-shuttle system called BusPlus has been developed as a way to improve service while keeping costs similar to current levels. The system, which has been described previously, uses a high-frequency bus service to link hubs placed at community centres. Multi-hire taxis are used to shuttle passengers between hubs and their local bus stops. Passengers are required to book their journey at least 15 minutes before travel, but are then able to travel much more conveniently. A single ticket covers the cost of the whole journey.

A trial of such a system is being planned for the city of Canberra, Australia. Canberra is a beautiful city, but the tree-lined streets, large domestic housing blocks, and many parks that make it one of the most liveable cities in Australia, also make it difficult to serve by public transport.

This paper will describe the operation of the BusPlus system. However, the main contribution is to discuss the design decisions made, and the many fine details that must be addressed, in order to get a great idea out of the lab and onto the street. For example, child safety concerns, details of cash payment options, and issues surrounding the use of the system by elderly people. The talk will be of interest to researchers and practitioners working in the implementation of innovative public transport.

4 - Simulation of Intermodal, Metropolitan Public Transport
Steven Harrod, Fabrizio Cerreto

The Technical University of Denmark, in cooperation with multiple partners, has commenced a large scale research project, entitled "IP-TOP", concerning the scheduling and integration of transport in the Copenhagen metropolitan area. A key task in this research is to investigate the connections between transit services (vehicles) and the timetabling of a very large network where a large proportion of travelers make one or more connections as part of their journey. Many of these connections are between bus and rail services, which have very different delay distributions and network correlations.

This presentation reviews the project goals and the tools available for simulation of rail and bus services. The final tool selections for IP-TOP will be revealed along with the rationale for their selection. The presentation will conclude with a discussion of whether the rail and bus networks will be simulated individually or simultaneously. Some preliminary delay data characteristics will also be discussed in the presentation.

■ TD-47
Tuesday, 14:30-16:00 - Graham Hills GH513, Level 5

MAI: A call to address grand challenges: a conversation between the OR community and the Voluntary Action Fund (Scotland)

Stream: Making An Impact 3 (MAI 3)
Invited session
Chair: *Jane Parkin*

1 - A call to address grand challenges: a conversation between the OR community and the Voluntary Action Fund (Scotland)

Miles Weaver, Jane Parkin, Steven Paxton, Anne-Marie Reilly

A recent article in the OR Society Magazine highlighted a growing need to address the "grand challenges" that we face as a society and desire to have a lasting legacy from Euro 2015 (Glasgow). Addressing "grand challenges' is very much in the history and tradition of Operational Research (OR), in the past saving millions of lives and protecting Britain, ultimately helping to liberate Europe. There are "grand challenges' facing us all in the UK and beyond, today. Lane (2010) argued that OR has considerable advantages to deal with strategic issues and grand challenges. However, in the area of sustainability, Weaver et al., (2013) found a limited number of contributions in ORS journals, mainly focused on environmental issues but significantly growing since the credit crisis crash in 2011.

The "grand challenges' in Glasgow will be outlined in conversation with the Voluntary Action Fund, long established Scottish grant maker, followed by break-out discussions to: 1) Discuss the nature of the problems and issues in relation to the host of OR methodologies, tools and techniques; 2) Explore how OR professionals can best promote and develop meaningful responses to make an impact in the areas identified

A 'call to action' and next steps will be identified by the participants to be shared amongst the OR community to address some of these grand challenges in Glasgow. Many will be equally applicable across Europe, and, indeed, worldwide.

■ TD-48
Tuesday, 14:30-16:00 - Graham Hilils GH510, Level 5

Competitive and Capacitated Location Problems

Stream: Location
Contributed session
Chair: *Boglárka G.-Tóth*

1 - Locating a shopping centre considering demand disaggregated by categories
Rafael Suárez-Vega, José Luis Gutiérrez-Acuña, Manuel Rodríguez-Diaz

This paper deals with the problem of locating a shopping centre. The demand was distributed in four categories (Food, Leisure, Household Equipment and Clothing). Due to the fact that some of these sectors do not provide essential services, a Huff model with a parameter that absorbs the lost demand when the attraction is not enough has been considered. Parameters for the Huff model has been estimated both globally (by means of Ordinary Least Squares and assuming the same effect for the parameters along the entire market) and locally (using Geographically Weighted Regression and considering that parameters depend on the customers' location). The proposed model has been applied to a real data case on the island of Gran Canaria (Spain) in order to determine the best location for a shopping centre. Finally, a study of the robustness of the solution with respect to the lost demand parameter and a comparison between the solutions obtained using both the global and the local calibration methods are presented.

2 - Algorithm for modular-capacitated multi-period plant location problem with capacity closure constraint
Vikram Batra, Yogesh Agarwal

Selection of location for manufacturing plants is a strategic decision for an organization. Shifts in customer demand during the plant's lifespan can alter the attractiveness of a particular location, turning an optimal location of one period into a strategic blunder for the future. Closure or relocation of plants may be unviable, due to external factors and these inefficient locations would result in excess transportation costs, which cannot be offset, no matter how well the production plans or inventory are optimized in the operational level plans. The complexity of modeling such problems has limited much of the traditional facility location research to simplified static (single-period) models. This paper presents an algorithm to generate the optimal sequence for opening plants and installing modular capacity units across locations during a multi-period planning horizon. The objective is to achieve the lowest cumulative cost of transportation and capital investment. The algorithm was applied to a randomly generated set of locations (50 customers and 20 candidate plants) over a 10 year demand horizon. The

multi-period model achieved a capacity sequence with a cumulative cost 3.2% lower than the year-on-year planned sequence. To demonstrate the algorithm on an industry application, it was applied for the Indian automobile industry. This industry is a good candidate for the model as it has high transportation costs and capital is built in modular assembly lines.

3 - An iterated local search algorithm for the capacitated p-median problem

Mariana Guersola, Maria Teresinha Arns Steiner

The capacitated p-median problem (CPMP) is a location problem where a set of customers with specific demands is to be partitioned into clusters, such that the sum of the distances between each customer and the median associated with its cluster is minimized, and the sum of demands of all customers in each cluster does not exceed its capacity. The CPMP has various applications such as design of distribution networks and vehicle routing. Heuristic and metaheuristic procedures have been created in order to solve CPMPs, justified by the fact that the problem is NP-hard. The Iterated Local Search (ILS) algorithm has proven to be a successful approach to solve different combinatorial optimization problems. We developed an ILS algorithm for the CPMP, which was first experimented in benchmark instances, obtaining, in most cases, the same results as the best found in the literature, and in other cases presenting less than 2% error, but with lower computational time. The ILS was also applied to a case study in a liquefied gas distributor in Brazil, which needs to nominate each customer requiring refueling to one of the available trucks. Compared to the previous techniques used by the company, the results showed an 11% distances reduction, and the advantage of never assigning for a truck more demands than its capacity. In comparison to the mathematical model, the case study results showed the ILS reached the best solution in almost 60% of tests and had errors lower than 2% in others.

4 - Huff-like Stackelberg problem on networks with quality variables

Boglárka G.-Tóth, Kristóf Kovács

In a Stackelberg location problem two firms compete for market share, they both aim to locate one or more facilities trying to maximize their profit. The leader is the firm that locates first, the follower locates with full knowledge of the leader's location. This leads to a bi-level optimization problem, where the leader has to take into account the possible locations of the follower when calculating its objective function, so that it is optimal after the follower locates its facilities.

We consider the problem on networks, where the demand is inelastic and concentrated in the vertices of the network. The competition is static and the customer's choice is probabilistic. The facilities can be located on the edges of the network and both firms aim to locate only one new facility. The objective function is the profit obtained by the chain, which is the market share captured by it minus its operational costs. We incorporate the qualities of the facilities into the model, assuming that the quality of the players new facilities are discrete variables.

We tackle the problem using an embedded Branch and Bound method into another, with interval arithmetic, and DC bounds for both the leader and the follower. In the talk computational results for small and medium sized networks will be presented.

■ TD-49

Tuesday, 14:30-16:00 - Graham Hills GH511, Level 5

Location-Routing

Stream: Location, Logistics, Transportation (contributed)
Contributed session
Chair: *Diego Ruiz-Hernandez*

1 - Distribution systems design for public bicycle sharing systems with routing considerations

Jenn-rong Lin, Chung-Wei Shen

We formulate and analyze a strategic design model for public bicycle distribution systems with strategic and operational concerns simultaneously. The key design decisions considered are: the number and locations of maintenance centers, the number of transport vehicles and

which vehicle should be dispatched at which open maintenance center, the vehicle routing between open maintenance centers and the rental stations, and the transported qualities of vandalized bikes and usable bikes between stations and maintenance centers. The problem is formulated as a mixed integer program. Finally, the model is applied to design a distribution system for U-Bike Taipei.

2 - A branch-and-cut algorithm for the flow intercepting facility location and routing problem

Claudio Sterle, Maurizio Boccia, Teodor Gabriel Crainic, Antonio Sforza

In the last years one-echelon and two-echelon location routing problems (LRP) have been studied and adopted in tackling the problem of designing a freight distribution system for urban areas in the context of City Logistics. In LRPs location decisions concern the number and position of one or more types of logistic plants, whereas routing decisions concern the definition of dedicated or multi-stop routes of one or more kinds of vehicles. In the current literature, location decisions have been generally tackled considering the logistic plants as flow generating facilities. Hence, classical facility location problems, e.g., p-median and simple plant facility location problems, have been integrated with routing decisions. This choice, in some cases, has several drawbacks which do not allow to design a cost-effective system and do not allow to take into account specific features of the design problem under investigation (e.g., structure of the urban area; multi-commodity flows, etc.). In order to overcome these drawbacks, we propose in this work a new location-routing model for the design of a city logistics system, where location decisions are tackled considering the logistic plants as flow intercepting facilities (FIFLRP). The problem is formulated by an integer linear programming model and solved by branch-and-cut algorithm based on several cuts derived from the literature and adapted to the specific problem. Finally results on test instances are presented.

3 - Practical benchmarks for location-routing decisions via approximation algorithms

Diego Ruiz-Hernandez, Mozart Menezes, Vedat Verter

Large scale location-routing problems appear frequently in real life network design problems. In many cases, rather than an exact solution, a good feasible solution together with a lower bound on its cost is sufficient for making strategic decisions. In this work, we present a simple methodology to derive benchmarks that can be used for assessing the quality of certain distribution network, as well as pointing out possibilities for improvement. The proposed methodology incorporates the presence of various technological alternatives for transporting shipments between the different layers of a multi-level distribution network. Direct experience with three projects shows that the proposed analytical framework is amenable to develop managerial insights for fairly sizeable location routing problems.

■ TD-50

Tuesday, 14:30-16:00 - Graham Hills GH512, Level 5

Maritime Transportation 3

Stream: Maritime Transportation
Invited session
Chair: *Magnus Stålhane*

1 - Optimization of the power management system on the ship

Maja Krčum, Anita Gudelj

Electrical power system of a ship is consisted of power generators, consumers and distribution system. Shipboard power system is specific isolated system with no power supply from outside power system. Compared to terrestrial power systems it has a wider frequency and with the short cables leads to less power loss and voltage drop. There is a large portion of nonlinear loads relative to the power generation capability. In shipboard power system a large number of electric components are tightly coupled in a small space and when a fault happens in one part of the system may affect other parts of the shipboard power system. The Power Management System is a critical part of the control equipment in the ship. It is usually distributed on various control stations that can operate together and share information between each other or independently in case of special emergency situations in

which ship have to operate.The system becomes more complex by applying renewable energy system due to special rules implemented by International Maritime Organization (IMO). Safe, secure and efficient shipping on clean ocean, suggested by IMO requires the development of appropriate design, operational knowledge and assessment tools for energy efficient design and operation of ships. According mathematical model, presented in this paper, we optimize the use of sources for production electrical energy on the ship by using genetic algorithm.

2 - A new branch-and-price approach to the ship routing and scheduling problem with flexible cargo quantities
Magnus Stålhane, Guy Desaulniers

Tramp shipping is one of the three main modes of maritime transportation, where ships act like taxis and travel from port to port to pick up and deliver cargo. The ship routing and scheduling problem faced by tramp shipping companies is a maritime adaptation of the pickup and delivery problem with time windows, and is well studied both in the context of maritime and road-based transportation. However, one of the most used contracts of affreightment in tramp shipping is so called MOLOO-contracts where the shipping company may choose the exact cargo quantity to pick up and deliver from within a specified interval, and is paid per unit of cargo transported. In addition, the time spent in port depends on the cargo quantity (un)loaded. To solve this problem we present a branch-and-price method, where the subproblem is an elementary shortest path problem with resource constraints, and is solved using a labeling algorithm. Computational experiments show that our method outperforms existing methods from the literature.

3 - Vehicle Routing with Selective Pickups and Selective Deliveries in offshore supply logistics
Eirik Fernández Cuesta, Henrik Andersson, Kjetil Fagerholt

INTRODUCTION This paper considers a Vehicle Routing Problem with Selective Pickups and Selective Deliveries (VRPSPSD) originating from a real problem from offshore oil and gas supply logistics. The VRPSPSD is a vehicle routing problem where a set of ships deliver orders (or cargo) from the depot to a set of offshore platforms and picks up return orders at the platforms destined back to the depot. Both pickup and delivery orders are selective meaning that they are not compulsory and can be left behind for a later voyage. However, this comes at a penalty cost. In the current industry practice, the VRPSPSD is planned for only one voyage and there is also only one regular vessel available. To facilitate planning, a schedule for which facilities that are visited on a specific voyage is made a priori. This ensures predictability. However, because of uncertainty in the demand and in the reliability of the arrival of delivery orders at the depot, the capacity of the available ship could be insufficient and an additional ship needs to be chartered in. Chartering in additional ships at short notice is very expensive. In this paper we show how savings can be obtained by planning ahead and including the additional vessel in the plans from the beginning. To achieve this, a mathematical model for the VRPSPSD is presented and solved using commercial software. For large instances a solution methodology based on Tabu search that proves very efficient is proposed.

4 - The liquefied natural gas infrastructure selection and tanker routing problem - A case study
David Franz Koza, Anna Boleda Molas, Stefan Ropke

In this talk we present a combined infrastructure selection and tanker routing problem in the liquefied natural gas (LNG) business that is based on a business case study with a major liner shipping company. The decision problem is of strategic nature and consists of selecting a realizable infrastructure option at each port of demand as well as defining the size and number of tankers and their shipping routes used to transport the LNG from its source port to the ports of demand. The goal is to minimize combined annual investment and operational cost in the long term.

Both the introduction of global limits on sulphur and nitro oxide emissions as well as expectations about rising oil prices have increased the interest in LNG as an alternative fuel for vessels, including container ships. As the global LNG infrastructure is still underdeveloped, it requires both strategic investment as well as tactical routing decisions to make LNG available at the points of demand. To the best of our knowledge, the combined problem has not been addressed before.

We solve the problem in two steps. First, a set of sub-solutions is generated through enumeration. In the second step we solve a set-partitioning problem to determine the best combination of the previously generated sub-solutions. An extensive sensitivity analysis is conducted to account for the limited predictability of key parameter

values, to analyse the robustness of the obtained solution and to derive basic decision rules.

■ TD-51
Tuesday, 14:30-16:00 - Graham Hills GH542, Level 5

MAI: Do the right OR and do the OR right!

Stream: Making An Impact 1 (MAI 1)
Invited session
Chair: *Philip Jones*

1 - Do the right OR and do the OR right!
Philip Jones

This interactive tutorial introduces tools and techniques to help you do effective problem formulation and OR study design. Problem formulation identifies what the analysis is trying to achieve and what issues it needs to address. We will look at challenges like understanding your customer and stakeholders' needs and deciding on study scope. Once we have understood the problem, study design identifies what analysis we need to carry out and how. A generic OR study design process is used to highlight key design considerations and we will work through a number of practical approaches to develop the design. We will also make use of the resources within a visual knowledge map of problem structuring tools, so bring along your tablet or laptop. This talk is suitable for all, but several years' practitioner experience is desirable.

■ TD-52
Tuesday, 14:30-16:00 - Graham Hills GH554, Level 5

Stochastic and Dynamic Portfolio Optimization

Stream: Financial and Commodities Modeling
Invited session
Chair: *Milos Kopa*

1 - Linear Tests for Decreasing Absolute Risk Aversion Stochastic Dominance
Milos Kopa, Thierry Post, Yi Fang

We develop and implement linear formulations of convex stochastic dominance relations based on decreasing absolute risk aversion (DARA) for discrete and polyhedral choice sets. Our approach is based on a piecewise-exponential representation of utility and a local linear approximation to the exponentiation of log marginal utility. An empirical application to historical stock market data suggests that a passive stock market portfolio is DARA stochastic dominance inefficient relative to concentrated portfolios of small-cap stocks. The mean-variance rule and Nth-order stochastic dominance rules substantially underestimate the degree of market portfolio inefficiency because they do not penalize the unfavorable skewness of diversified portfolios, in violation of DARA.

2 - Minimizing Risks by Linear Programming Methods
Alejandro Balbás, Beatriz Balbas, Raquel Balbás

The optimization of risk functions is becoming very important in both Financial and Actuarial Mathematics. Applications in Mathematical Finance are asset allocation, pricing issues or risk management. Actuarial applications are premium calculations, optimal reinsurance or bonus-malus systems. The pioneering papers of Artzner et al. (1999) and Rockafellar et al. (2006), where the notions of coherent and the expectation bounded risk measure were respectively introduced, were later extended by many authors attempting to improve our risk analysis literature. Both papers above illustrated how the introduced new risk measures may capture aspects such as potential capital losses, which, in presence of asymmetry, cannot be estimated with the traditional standard deviation. Moreover, asymmetries provoke inconsistencies between the standard deviation and the second order stochastic dominance, but this caveat does not apply if one deals with alternative risk measures such as the absolute deviation or the conditional value at risk.

We will deal with an abstract problem involving the minimization of risk under perhaps ambiguous frameworks. Both scalar and vector risk measures may be considered, and there will not be restrictions about the properties of the underlying probability space, which implies that both static and dynamic approaches will fit our setting. Despite the level of generality, we will show that the risk minimization may be often addressed with Linear Programming methods.

3 - Pension Fund Optimal Investment Policy
Sebastiano Vitali, Milos Kopa, Vittorio Moriggia

The pension system has become more and more complex all over the Europe in the last decades. We present the definition of an individual optimal portfolio allocation in a Pension Plan prospective. In particular, we propose a Multistage Stochastic Program including a multi-criteria objective function and introducing stochastic dominance constraints with respect to a benchmark wealth. We suppose that the investor is risk adverse, then the optimal portfolio allocation depends on the minimization of the Average Value at Risk Deviation of the final wealth. Jointly, the portfolio must satisfy a wealth target in the final stage and one in an intermediate stage. Other classical constraints regard the pension funds rules, i.e., diversification constraints, contribution constraints, portfolio balance, etc. Stochasticity arises from the investor's salary process, the assets return process, the stochastic investment behavior and the correlation among them. The stochastic investor's behavior is modeled through a coefficient representing the investor's withdraw percentage during a specific stage. In particular, the withdraw decision can depend on the salary process with a direct or inverse relation. Numerical results show that we can achieve a time evolving balanced portfolio satisfying the investor's wishes.

4 - Multistage Portfolio Optimization with Probabilistic Constraints
Karel Lavicka

In this talk, we present a multistage stochastic programming problem with probabilistic constraints applied to an optimal portfolio selection. The constraints (chance or expectation) in this problem may be quite versatile, for example may also contain joint events from multiple time stages. Our solution approach is based on dynamic programming equations. The idea behind dynamic programming for such problems is the decomposition of the set of feasible policies. One additional risk parameter per each constraint allows us to write dynamic programming equations as in the risk-neutral case. It is shown that the risk parameter selection has to be a part of the optimal policy. Although these problems are nonconvex and hard to solve in general, we formulate a convex version of the portfolio selection problem and show some numerical results.

◼ TD-53
Tuesday, 14:30-16:00 - Graham Hills GH614, Level 6

Applications of Dynamical Models 3

Stream: Applications of Dynamical Models
Invited session
Chair: *Alberto Pinto*
Chair: *Bruno M.P. M. Oliveira*

1 - Edgeworthian prices in a random matching economy with selfishness
Bruno M.P. M. Oliveira, Alberto Pinto, Athanasios Yannacopoulos, Barbel Finkenstadt

We study a random matching economy, where pairs of participants are selected randomly to trade two goods. We show that under some fairly general and easy to check symmetry conditions, depending on the initial distribution of endowments and the agents preferences, the sequence of Edgeworthian prices in this economy converges to the Walrasian prices for this economy. Additionally, we associate a selfishness factor to each participant in this market. this brings up a game alike the prisoner's dilemma, where trade may occur in an asymmetric point in the core or may not even be allowed. We discuss how the selfishness affects the sequence of Edgeworthian prices.

2 - The impact of startup costs and the grid operator on the power price equilibrium
Miha Troha, Raphael Hauser

In this paper we propose a quadratic programming model that can be used for calculating the term structure of electricity prices while explicitly modeling startup costs of power plants. In contrast to other approaches presented in the literature, we incorporate the startup costs in a mathematically rigorous manner without relying on ad hoc heuristics. Moreover, we propose a tractable approach for estimating the startup costs of power plants based on their historical production. Through numerical simulations applied to the entire UK power grid, we demonstrate that the inclusion of startup costs is necessary for the modeling of electricity prices in realistic power systems. Numerical results show that startup costs make electricity prices very spiky. In the second part of the paper, we extend the initial model by including the grid operator who is responsible for managing the grid. Numerical simulations demonstrate that robust decision making of the grid operator can significantly decrease the number and severity of spikes in the electricity price and improve the reliability of the power grid.

3 - Solving EPEC problems with multiple Nash equilibria: application to energy-based models
David Pozo, Enzo Sauma, Javier Contreras

One common generalization of the Stackelberg game addressed in the literature is the so-called equilibrium problem with equilibrium constraints (EPEC) where multiple leaders state an equilibrium at the upper level and multiple followers state an equilibrium at the lower level. This problem is frequently non-linear and non-convex, thus, existence and uniqueness of equilibrium points are very difficult to prove. Although some interesting solution algorithms have been proposed for solving simple instances of EPEC games, a generalized theory and suitable solution algorithms have not been firmly established so far. The solutions obtained are usually stationary, which may be global equilibria, local equilibria or saddle points. Three algorithms have been proposed in the literature: (1) a diagonalization approach, (2) a simultaneous solution method, by writing the strong stationary necessary, and (3) a system of inequalities with equilibrium constraints. We propose a column-and-row decomposition technique for solving EPECs, which allows us to reach the global optimal solution (Nash equilibrium) and simultaneously selecting a meaningful Nash equilibrium. This decomposition technique has proved to be effective in improving tractability up to two orders of magnitude faster than classical approaches. The proposed algorithm is applied to the power system transmission expansion problem.

◼ TD-54
Tuesday, 14:30-16:00 - Graham Hills GH617, Level 6

Advances in Control Theory & System Dynamics

Stream: Control Theory & System Dynamics (contributed)
Contributed session
Chair: *Bo Hu*

1 - About Moreau-Yosida regularization of the minimal time crisis problem
Terence Bayen, Alain Rapaport

We study an optimal control problem where the cost functional to be minimized represents the so-called time of crisis i.e. the time spent by a trajectory solution of a control system outside a given set K. This functional can be expressed using the indicator of K, that is discontinuous preventing the use of the standard Pontryagin's Principle. We consider a regularization scheme of the problem based on the Moreau-Yosida approximation of the characteristic function of K. We prove the convergence of an optimal sequence for the approximated problem to an optimal solution of the original problem. We then investigate the convergence of the adjoint vector given by Pontryagin's Principle when the regularization parameter goes to zero. Finally, we study an example illustrating the convergence property and we compute explicitly an optimal feedback policy and the value function.

2 - Nonlinear Modeling and Simulation, and Linear Control of an Unmanned Underwater Vehicle
Ruxandra Botez

Research in the modeling of unmanned underwater vehicles UUVs is here presented, mainly on the optimization of hydrodynamic forces, gravity and buoyancy effects and propulsion forces interactions. The accuracy of the unmanned underwater vehicle simulation is directly linked to its modeling accuracy. A nonlinear six degrees of freedom model is developed with the aim to keep the interactions between longitudinal and lateral dynamics modes. Firstly, a nonlinear model for the UUV is built in order to analyze the dynamics of immersed vehicles. Then, this model is controlled in order to consume a minimum amount of energy. Thus, a global nonlinear model of the thrust-vectored vehicle is constructed to explain the interactions between the design and the modeling of the four-propeller vehicle. Proportional Integral Derivative (PID) control regulators are implemented using an input-output feedback linearization - in addition, white noise robustness and actuators and motors inner-loop controls are also studied.

3 - Analysis and Optimal Control of a Discrete Time Infinite Buffer Batch-Size Dependent Service System with Versatile Policy
Arunaya Maity, *Umesh Gupta*

This paper considers a single channel, infinite buffer, batch transmission queueing system in a slotted time set up. Messages arrive according to the Bernoulli process and the processing time is arbitrarily distributed and depends on the number messages undergoing transmission. The service is provided according to versatile service policy i.e., the server is empowered to decide the number of messages (threshold bound) to be transmitted on beforehand. Study of the present model may help in understanding the behavior or related performances of synchronous communication systems (slotted ALOHA) or packet switching systems with time slotting, ATM multiplexer in B-ISDN, circuit-switched time-division multiple access (TDMA) systems etc. We derive the queue length distribution in post transmission epochs using embedded Markov chain technique and probability generating function approach. Furthermore, we establish the relationships between arbitrary and post transmission epoch probabilities using basic "rate in - rate out" principle, which absolves of any further considerations of random variables as well as complex renewal arguments. We also obtain several important performance characteristics and construct a related cost model for the present model, which may be very useful to the vendors for optimal utilization of the facsimile systems, by possibly controlling only the sensitive parameters in pre-implementation stage. Some illustrative numerical examples are also presented.

4 - System dynamics stocks used to model electric power sector
Bo Hu, *Armin Leopold*

System dynamics modeling has been used for strategic energy planning and policy analysis for more than fifty years. We present an review of system dynamics studies addressing diverse issues in the electric power sector. The focus is to analyze the usage of stocks within a variety of system dynamics models from a methodological point of view. According to literature, stocks are considered as accumulations that characterize the state of the system and generate the information upon which decisions and actions are based. Furthermore, stocks create delays by accumulating the difference between the inflow to a process and its outflow. Due to the fact that electricity can be easily transported but hardly stored, modeling power supply systems with system dynamics presents a special challenge. With this review, we attempt to show how stocks are used in this particular field and work out some recommendations of the proper usage of stocks in the electric power sector.

■ TD-55
Tuesday, 14:30-16:00 - Graham Hills GH626, Level 6

Operational Research in Management Accounting

Stream: Operational Research in Financial and Management Accounting
Invited session
Chair: *Catherine Plante*

1 - Tax Exempt Hospitals in the State of New Hampshire
Catherine Plante

Whether nonprofit hospitals provide enough community benefit to justify their tax-exempt status continues to be an issue for legislatures and taxpayers in the communities that support the hospitals. If nonprofit hospitals are maximizing their charitable mission and justifying their tax-exempt status, they will provide the maximum amount of charitable care given their financial constraints. Demand for uncompensated care is increasing which puts more pressure on hospitals' financial position. Determining whether nonprofit hospitals are fulfilling their nonprofit mission is increasingly important as healthcare dollars are squeezed. State budgets are cutting support for charity care while the implementation of the Affordable Care Act is adding uncertainty. The cost/benefit of having multimillion dollar entities not paying taxes is becoming a political issue. There have been cases of hospitals getting their nonprofit status revoked for not providing enough community benefit but these cases are rare. Previous research has hypothesized that nonprofit hospitals that compete directly with for-profit hospitals act differently than nonprofit hospitals that do not face this type of competition. This study examines hospitals in the state of New Hampshire to determine if they provide enough charity care to justify their tax exempt status. New Hampshire provides a unique environment in which to study the provision of charity care because of the homogeneous nature of the hospitals.

2 - Can the Implementation of EVA Performance Evaluation Restrain Over-Investment of State-owned Enterprises
Zhi Wang

Over-investment is one of the most urgent problems faced by Chinese economy development. The State-owned Assets Supervision and Administration Commission (SASAC) introduced EVA performance evaluation in 2010 to restrain over-investment by guiding the investment decisions of central holdings. Does this measure have its expected effect? This paper examines empirically the governance effect of the implementation of EVA on over-investment, from both vertical and horizontal angles. Our conclusion not only provides empirical support for the SASAC to further promote EVA performance evaluation, and to improve investment efficiency of the central holdings, but also demonstrates a beneficial approach to govern state-owned enterprises' over-investment and avoid operational failures.

3 - The Perception of Risk Management Among Safety Professionals in the UK Commercial Organisations: A Comparative Study
Shahzeb Ali Malik, *Barry Holt*

This research involves looking at the perception of risk management from a safety perspective within selected commercial organisations in the UK. Through this research, we have gathered key findings from qualitative data analysis of interview transcripts. Several semi-structured interviews were conducted with safety professionals working in the UK commercial organisations to gather their views on how risk management is perceived at different levels of health and safety within the organisations. The NVIVO software package was used to execute the qualitative analysis, the main outcome of which is the identification of five critical themes for the divergent range of organisations that took part in this research.

4 - Impact of Market Orientation on the Performance of Private Universities in Pakistan
Naveed Iqbal Chaudhry

This study aimed to investigate the effects of market orientation on the performance of private universities in Pakistan. The effects of market orientation are visualized on different performance measures which were developed for universities specifically. The data was collected through survey strategy from 300 faculty members of 15 randomly selected private universities of Pakistan. The survey consisted of questionnaire stating the measures of market orientation and performance. Multiple regression analysis was performed to test the hypothesis by using AMOS. Findings of this study confirm the relationship of market orientation with performance measures. The market orientation has positive significant relationship with student retention, student growth, market share, quality of teaching & services, research performance and overall performance. The results of this study point out the importance of market orientation in private universities. The universities with high level of market orientation will have positive performance outcomes in terms of higher level of student retention.

■ TD-60

Tuesday, 14:30-16:00 - Graham Hills GH813, Level 8

Heuristics for Vehicle Routing Problems

Stream: Routing I - Models and Methods
Invited session
Chair: *Véronique François*

1 - An Adaptive Metaheuristic for Vehicle Routing Problems with Time Windows and Multiple Service Workers

Gerald Senarclens de Grancy

Distribution planning in urban areas faces a lack of available parking space at customer sites. One approach to mitigate the issue is to cluster nearby customers around known parking locations. Deliveries from each parking location to its assigned customers occur by foot. These lead to long service times at each of the clusters. However, long service times in conjunction with time windows can lead to inefficient routes as nearby customer clusters with overlapping service times may not be connected. As a consequence, assigning additional service workers to each vehicle is a strategy to reduce service times. The trade-off between paying additional workers to reduce costs for vehicles and driving creates a new decision problem called the vehicle routing problem with time windows and multiple service workers (VRPTWMS).

The present work introduces a stochastic cluster first, route second algorithm. These two stages are then linked together with a feedback loop based on the well established ant colony optimization metaheuristic. This allows learning from prior results and leads to vastly improved solution quality. For each of the used benchmark instances new best known solutions were generated. Furthermore, it is shown that applying the concept of bi-modal transportation potentially reduces both cost and environmental impact in regular vehicle routing problems with time windows.

2 - A Tabu Search Algorithm for the Split Delivery Capacitated Arc Routing Problem

Wasin Padungwech, Jonathan Thompson, Rhyd Lewis

In the Capacitated Arc Routing Problem (CARP), the goal is to find a minimum-cost set of routes that covers a specified set of edges (called required edges) in a graph. Each required edge has an assigned demand, and the sum of demands covered in each route must not exceed the amount called capacity. This problem arises in various situations including waste collection, street sweeping and winter gritting. Recently, attention has been given to a variant of the CARP called the Split Delivery Capacitated Arc Routing Problem (SDCARP) where split deliveries are allowed; in other words, required edges may be covered by more than one route (or "serviced by more than one vehicle'). It is hoped that split deliveries can reduce the total cost as vehicles are no longer forced to service an edge fully, and so they can service some edges even if its remaining capacity is smaller than the remaining demand of any required edge. In addition to a smaller total cost, this could mean that fewer vehicles/routes are needed. Introduced by Golden and Wong in 1981, the CARP is NP-hard and, as a generalisation of the CARP, so is the SDCARP. This suggests the need for heuristic algorithms that can find "good' solutions in reasonable time. Tabu search is one of the metaheuristics that have been shown to give strong results when applied to the CARP. In this talk, we review how we can apply such methods to the SDCARP.

3 - Bi-objective heuristics for solving the robust vehicle routing problem with uncertain travel times and demands

Elyn Lizeth Solano Charris, Christian Prins, Andréa Cynthia Santos

The vehicle routing problem focused in this study is subjected to uncertain travel times and demands. The uncertain data are handled in the objective functions by means of robust optimization. Thus, the problem is referred as bi-objective Robust Vehicle Routing (bi-RVRP) and it is defined on a complete digraph with a set of vertices representing the customers and depot, and a set of arcs corresponding to the network transportation. Uncertain data for travel times are modeled as a set of discrete scenarios, where a scenario specifies an assignation of costs to every arc. Moreover, an expected demand is associated with each customer and uncertainties over the demands are modeled as an interval, which represent the deviation from the expected values. A fleet of identical vehicles with a fixed capacity is available at the depot.

The problem consists in defining a set of routes starting and ending at the depot, visiting each customer once and respecting vehicle capacities. The goal is to minimize simultaneously the worst total travel times over all the scenarios and the maximum total unmet demands over a bounded set of scenarios. The bi-RVRP finds applications in urban transportation. We propose multi-objective metaheuristics based on evolutionary algorithms such as NSGAII and MOEA. Results are provided for medium-size instances and different evaluation criteria are applied to measure the performance of the proposed bi-objective heuristics.

■ TD-61

Tuesday, 14:30-16:00 - Graham Hills GH816, Level 8

Shared Mobility Systems - II

Stream: Routing II - Emerging Applications
Invited session
Chair: *Gunes Erdogan*

1 - A bike sharing system design with a Simulated Annealing algorithm

Javier Duran

This work is motivated by the need of an efficient design of a bike sharing system in the city of Concepción, Chile. The objective is to determine where to locate the stations of the system and how many bicycles assign to every facility, in order to satisfy the demand minimizing the total cost of construction and operation of the system. To meet this objective an integer programming problem is formulated based on the "Capacitated Facility Location Problem' (CFLP) with addition of lower bounds to the open facilities. The costs considered are the construction and maintenance of the stations, the operation cost of the bicycles and a penalty to the distance between the users and the station.

Since it's a combinatorial problem it's not possible to find the optimal solution on reasonable time, so a Simulated Annealing algorithm is developed to find near optimal solutions, metaheuristic that has shown good results on this kind of problems. This method is implemented in MATLAB and is tested in several randomly generated instances of different sizes, comparing the results with a local search algorithm. The results show that the Simulated Annealing performs well and obtains good approximations. Also the previous method is applied to an instance based on the city of Concepcion, obtaining a good design to a bike sharing system in this city, which could make more sustainable the transit network of this metropolitan area.

2 - Optimizing vehicle and personnel relocations in one-way car-sharing systems with reservations

Burak Boyaci, Konstantinos G. Zografos, Nikolas Geroliminis

Car-sharing (also known as shared-use vehicle) is a concept for car rental which enables people to rent cars for short periods of time. Vehicle relocation operations and scheduling of vehicle-relocation personnel activities are important aspects of one-way car-sharing systems, affecting both the cost and the level of service they offer. In this research, we provide a framework for optimizing vehicle and personnel relocation operations for non-floating one-way car-sharing systems with reservations and dynamic relocations (ie relocations handled all day as long as there is a personnel available). In addition to optimizing relocation operations, the proposed framework supports decisions related to the acceptance of service requests. The framework includes three interrelated models: (1) a station clustering model which groups stations on the basis of travel time needed to relocate personnel with and without vehicles, (2) an integrated multi-objective network flow model for optimizing vehicle and personnel relocations on a time-space diagram, and (3) a personnel flow model for generating feasible relocation personnel rosters. We report results on the applications of the proposed framework using data from the one-way car-sharing system operating in Nice, France.

3 - A feasibility study for a taxi sharing system in the city of Milan

Alessandro Giovannini

To meet the challenge of improving sustainable urban mobility services, we propose a shared door-to-door service provided by the existing taxi fleet, and we refer to this service as Taxi Sharing. Algorithms to solve the Dial-a-Ride Problem (DARP) have been developed in the last decades in order to optimize door-to-door transportation services with wide constraints and a low number of vehicles. In the Taxi Sharing system we propose narrow time windows on pick-up and delivery time and the service is provided by many vehicles. These features allow to enumerate all possible subsets of incoming users' requests for each vehicle and to compute an optimal set of routes in real time by solving a large set covering problem with state-of-the-art integer linear programming solvers. Preliminary results obtained from simulations with a software prototype we have developed in collaboration with AMAT—Agenzia Mobilità Ambiente Territorio for the city of Milan suggest that Taxi Sharing would allow the municipality of Milan to enhance and to better differentiate the offer of mobility services without subsidizing programs and high investments. In this paper we present the main features of the Taxi Sharing system and the optimization algorithms it relies upon; simulation results will be discussed, whose aim is to achieve insight into the tradeoff between some relevant performance indicators, such as the number of requests served per unit of time and the average waiting time and travel time.

■ TD-62

Tuesday, 14:30-16:00 - Livingstone LT203, Level 2

Operations Research 8

Stream: Operations Research, other
Contributed session
Chair: *Marina Vinot*

1 - About the influence of "Experts factors' in risk management process for safety, security and environment
Myriam Merad

Public expertise in safety, security and environment (SSE) is a process that is increasingly submitted to control and transparency. As decision-making, the exercise of expertise involves subjectivity and judgment. An oversight, a monitoring and an aiding approach is therefore required for its conduct and its governance. This paper proposes a novel way of embedding ethical aspects and participative decision-making elements into the process of risk assessment and risks management. Based on their experience feedback, the authors first propose some early contributions to study the validity and the legitimacy of expertise in SSE. In the second part of the paper, the authors give an overview on how public expertise is organized in France and how the problems and the conclusions are framed in SSE. Finally, the authors propose a generic integrated framework for public expertise that constitutes the "responsible exercise of expertise'. This framework allows framing a valid and a legitimate expertise process and its conclusions.

2 - Understanding the Impact of Substitution and Synergy in Multi-channel Marketing of a New Product Introduction
Dmitry Krass, *Oded Berman*, *Vahideh Sadat Abedi*

In this work, we present a demand model for a new product where at any point of time demand is influenced by multiple marketing channels in addition to the word of mouth recommendations from previous purchases. It is well established that the role of substitutive and synergic interactions between channels need to be properly accounted in the marketing resource allocation strategies of the firm. However, the existing literature focuses on only one of these two types of interactions and remains silent whether they can co-exist and when one dominates the other. We show that channels can possibly interact both substitutively and synergistically at the same time. We derive several insights on the implications of this co-existence and its influence on the marketing resource allocation strategies of the firm. Among them, we find that when channels have limited effectiveness on demand they initially interact mainly synergically in order to mature the word of mouth process, after which word of mouth can significantly influence the demand 'for free'. Then at this stage, the channels mainly behave substitutively to fine-tune the impact of word of mouth on demand. We find that in the presence of substitution, it is never optimal to spend on an ineffective channel.

3 - Prudence and Downside Risk Aversion under Cumulative Prospect Theory
Qiulin Yang, *James Huang*, *Zhan Pang*

In this paper we study the relationship between prudence and the intensity of downside risk aversion under prospect theory. Chiu (Chiu, W. H. (2005), Skewness Preference, Risk Aversion, and the Precedence Relations on Stochastic Changes, Management Science 12, 1816-1828) shows that in the case of concave utility functions, the greater the prudence measure, the greater the intensity of downside risk aversion. However, we show that in the case of convex utility functions, in contrast to the preceding case, the smaller the prudence measure, the greater the intensity of downside risk aversion. The above two contrasting results have implications for the cases of S-shaped utility functions. We show that in these cases, increasing the prudence measure on the concave sections of a utility function and decreasing the measure on the convex sections will increase the intensity of downside risk aversion. We then extend the above analysis to the cases under cumulative prospect theory.

4 - REPLACED — Simultaneously Handling Routing And Scheduling Through a GRASPxELS Algorithm
Marina Vinot, *Philippe Lacomme*, *Aziz Moukrim*, *Alain Quilliot*, *Daniele Vigo*

Production and transportation scheduling problems (PTSP) are particularly important in world with an increasing global competition. The problem which we study here was first addressed by Geismar and al. in 2008 and involves a single-machine-single-vehicle integrated production and transportation of short lifespan products. More precisely, we have a machine M, a vehicle V with capacity Q, together with customers each requiring the delivery of q(i) units of a given product. In addition products must be delivered to customers within a time which does not exceed some lifespan value B. The goal is to simultaneously schedule production and transportation by minimizing the overall makespan. We adopt a GRASPxELS approach to define the sequences which adopts an alternative way of constructing sequences of operations as collections of feasible tours, while implementing a 2-label Split process which allows taking into account the lifespan constraint in a more flexible way. Also, we test the impact of relaxing the no-wait restriction while solving the 2-machine flow shop The GRASPxELS algorithm introduces a control on the local search loop which consists into compromising between respective production and routing criteria. We test our algorithm on Geismar and al. instances as well as on more general instances.

■ TD-66

Tuesday, 14:30-16:00 - Livingstone LT209, Level 2

Graphs

Stream: Optimization
Invited session
Chair: *Cotté Grégoire*

1 - The AutoGraphiX-III system
Gilles Caporossi

More than fifteen years after the beginning of the development of AutoGraphiX (AGX), a third version of the software is made available. Since the program was rewritten from scratch, it was the opportunity to look forward and consider new avenues. From the user's point of view, the interface is completely changed, which allows the display of multiple information which was not possible in the previous versions. However, one of the main improvements is that it is designed to help researchers in the field of complex networks. In these days when increasing research is applied to complex networks (such as social networks), the use of quantities related to vertices, indicating the centrality (the importance of an actor in the network measured as a topological indicator) naturally leads researchers toward the mathematical study of these quantities. This new paradigm implies a complete change in the optimization algorithm that now natively handles multi objective optimization problems involving vertex-related measures.

2 - Two formulations for the K-partitioning problem
Zacharie Ales

We introduce an edge-representative formulation for the K-partitioning problem based on representative variables. We show how this formulation can be extended to improve its linear relaxation.

A branch-and-cut algorithm based on a polyhedral study and a thorough cutting-plane strategy at the root node is described. We illustrate our approach with numerical results on some random hard instances.

3 - A general framework for finding d_transversals in graphs
Cotté Grégoire, *Marie-Christine Costa*, *Christophe Picouleau*

Let P be an optimisation problem on a finite set of elements V, where an optimal solution of P is a subset of V. A d-transversal T is a subset of V such that the intersection between T and any optimal solution of P contains at least d elements of V. A d-transversal is optimum when its size is minimum. Generally, the minimum transversal problem can be modelized as a bilevel 0-1 program which can be transformed in a 0-1 program with potentially an exponential number of constraints.

We propose a general framework to solve this problem when P is modelized by a 0-1 mathematical program. We test the efficiency of this approach for the case where P is the maximum stable set or the maximum matching problem. In these cases, P can be modelized as a 0-1 linear program. Our algorithm is based on a constraints generation method and use a 0-1 linear program solver. We present numerical results for both problems.

■ TD-67
Tuesday, 14:30-16:00 - Livingstone LT210, Level 2

Exact Methods for Routing Problems I

Stream: Combinatorial Optimization
Invited session
Chair: *Francesca Vocaturo*

1 - Mixed-Policy Recourse Strategies for the Vehicle Routing Problem with Stochastic Demands
Michel Gendreau, *Majid Khoshghalb*, *Ola Jabali*, *Walter Rei*

In the Vehicle Routing Problem with Stochastic Demands (VRPSD), a homogeneous fleet of vehicles serves a set of customers with stochastic demands. The exact demand of each customer is only determined upon arrival at the customer's location, but the demand distribution is known in advance and allows to plan routes, which simply specify the sequence of customers that each vehicle should visit. Due to the stochastic nature of demand, a planned route may fail to serve a customer, because its demand exceeds the residual capacity of the vehicle. Such an event is called a route failure. When a route fails, the vehicle must perform a recourse action by returning to the depot to replenish its capacity before proceeding with the remaining customers. This traditional recourse framework is quite rigid and it does not always make sense to wait until the route failure is confirmed before going back to the depot. In this talk, we consider more flexible recourse actions that allow a preventive return to the depot when the residual capacity becomes too low. The specific strategies that we study are based on decision rules that account both for the distance to the depot and the risk of route failure. These policy-based recourse actions are implemented within an exact solution technique for the VRPSD. An extensive computational study shows that significant savings on recourse cost can be achieved even for instances of small size, compared to the traditional recourse approach.

2 - A Branch-Price-and-Cut Algorithm for the Commodity Constrained Split Delivery Vehicle Routing Problem
Claudia Archetti, *Nicola Bianchessi*, *M. Grazia Speranza*

We consider the Commodity constrained Split Delivery Vehicle Routing Problem (CSDVRP), a routing problem where customers may request multiple commodities. The vehicles can deliver any set of commodities, and multiple visits to a customer are allowed only if the customer requests multiple commodities. If the customer is visited more than once, the different vehicles will deliver different sets of commodities. Allowing the splitting of the demand of a customer only for different commodities may be more costly than allowing also the splitting of each individual commodity, but at the same time it is easier to organize and more acceptable to customers. We model the C-SDVRP

by means of a set partitioning formulation and present a branch-price-and-cut algorithm. In the pricing phase, the ng-path relaxation of a constrained elementary shortest path problem is solved with a label setting dynamic programming algorithm. Moreover, at each pricing iteration, a bi-objective problem is solved in order to exclude dominated solutions. Capacity cuts are added to strengthen the lower bound. We solve to optimality instances with up to 40 customers and 3 commodities per customer within 2 hours of computing time.

3 - A Branch-and-Cut Algorithm for Truck and Trailer Routing Problem
Jose M. Belenguer, *Enrique Benavent*, *Claudio Contardo*, *Juan G. Villegas*

The Truck and Trailer Routing Problem (TTRP) is a variant of the Vehicle Routing Problem (VRP) in which customers must be served by a fleet of vehicles that consists of trucks and trailers. Each route, which starts and ends in a depot, is assigned to either a truck or a truck pulling a trailer (this combination is called train). The presence of accessibility restrictions makes some customers to be only served by a truck without the trailer. Therefore, in certain locations called satellites, the truck can detach its trailer, perform a number of subtours (i. e. truck trips) rooted at the satellite and re-attach the trailer to continue the train route.

In this work we propose a new formulation for TTRP, some families of valid constraints and a branch-and-cut algorithm to solve the problem. The computational results show that the algorithm is able to solve instances of medium size.

4 - An Exact Algorithm for the Undirected Capacitated General Routing Problem with Profits
Francesca Vocaturo, *Claudia Archetti*, *Luca Bertazzi*, *Demetrio Laganà*

We focus on the Undirected Capacitated General Routing Problem with Profits (UCGRPP). This problem is defined on an undirected graph where a subset of vertices and edges correspond to customers which are associated with a given profit and demand. The profit of each customer can be collected at most once. A fleet of homogeneous capacitated vehicles is given to serve the customers. The objective is to find the vehicle routes that maximize the difference between the total collected profit and the traveling cost in such a way that the demand collected by each vehicle does not exceed the capacity and that the total duration of each route is not greater than a given time limit. We propose a two-phase approach for the solution of the UCGRPP. In the first phase, a branch-and-cut method is used to solve an aggregate formulation and to identify a cut pool of aggregate valid inequalities to be used in the second phase, where a branch-and-cut method is implemented to optimally solve the UCGRPP. We demonstrate the effectiveness of the solution approach through an extensive computational study.

■ TD-69
Tuesday, 14:30-16:00 - Livingstone LT212, Level 2

Regression and Its Applications

Stream: Computational Statistics
Invited session
Chair: *Ersin Uysal*
Chair: *Pakize Taylan*

1 - Simultaneous Stochastic and Gradient Approach to Neural Network Learning for Classification and Regression
Paulito Palmes

The tendency of backpropagation to be stuck in local optima is a well-known problem in ANN learning. We approach this issue by alternately minimizing both ANN's RMSE and classification accuracy using gradient descent and stochastic mutation. Stochastic mutation compensates gradient descent shortcoming by providing the needed push to overcome local optima. Our simulation indicates that this simple mechanism improves ANN performance in classification and regression problems.

2 - Modeling with Nonparametric Logistic Regression Based on Generalized Additive Models and B-Splines

Pakize Taylan, Ersin Uysal, Gerhard-Wilhelm Weber

The most widely used model in medical research and classification or risk scoring is the nonparametric logistic regression that models the expectation of a dichotomous response variable with the model $\log[p(x)/(1-p(x))]$, where $p(x)$ is conditional probability of dichotomous response variable given input data . Logistic regression models are usually fit by maximum likelihood method. In this study, it is proposed conditional probability modeling by generalized additive model using B-splines as smooth functions. The method is illustrated with a example, and it is compared to existing techniques such as linear logistic regression.

■ TD-71

Tuesday, 14:30-16:00 - Livingstone LT307, Level 3

Telecommunications and Network Optimization

Stream: Telecommunications and Network Optimization
Invited session
Chair: *Dilek Gunnec*

1 - A scalable approach for distance-bounded disjoint paths problem in Telecommunication Networks

Cemalettin Ozturk, Alejandro Arbelaez, Deepak Mehta, Barry Osullivan, Luis Quesada

Many optical network design problems arising in access and core optical networks require connectivity between a given set of pairs of nodes under path-length constraints. For example, in the context of LR-PON access network there is a limit on the length of the fibre between an exchange-site and its metro-core node and in the transparent optical core network the length of fibre between each pair of metro-core nodes must be within a given threshold. An inherent feature of these networks is that they are vulnerable to a failure. Therefore, it is often important to provide resiliency by ensuring that a given set of pairs of nodes are connected through at least two disjoint paths while respecting the path-length constraints. Minimising the cost associated with the fibre while maximising the disjointness for a given network is a very challenging task. Here the reference network typically corresponds to a road network of a given country. We develop and present a general approach that is scalable for solving very large instances of this kind of problem.

2 - Heuristic based routing algorithm for a Network on Chip (NoC)

Marc Sevaux, Asma Benmessaoud Gabis

In electronic design, communications in Networks on Chip (NoC) is one of the most important aspect to take into account after the effective material design. In fact, since it is a miniature architecture, communication has to be efficient, to keep good NoC performance (power consumption, latency and throughput) and to satisfy NoC routing objectives (deadlock and livelock freedom, no congestion and fault tolerance). To handle these constraints, some existing protocols propose solutions with the use of virtual channels, routing tables, Q-learning methods and metaheuristics. These techniques generate sometimes negative impacts on the NoC performance.

In this context, a novel fully adaptive routing algorithm called HRA (Heuristic Routing Algorithm) is developed. It uses a Variable Neighborhood Search (VNS) algorithm to find a local optimal neighbor at each hop until reaching the destination node. VNS is mainly based on a local search strategy represented there by the A* (A Star) heuristic based search method. The advantage of using heuristics is a prediction of the best optimal path according to the network state. The combination of both methods allows the avoidance of deadlock without using virtual channels, dealing with congestion and ensuring fault tolerance. Experiments show that HRA offers energy consumption comparable to XY and low transmission packet latencies while ensuring a good reliability rate.

3 - Second Order Conic Reformulation of a Wireless Network Design Problem

Emine Gundogdu, Sinan Gürel

In this study, we consider a wireless network design problem. The problem involves finding access points to open and power levels to install on the access points, along with the assignment of customer points to access points so that the total cost is minimized. The problem can be formulated as a mixed integer nonlinear program. Gendron et al. (2014) propose a Combinatorial Benders Decomposition approach which eliminates nonlinear constraints and solves linear sub problems. In this work, we present a mixed integer second order conic (MISOCP) reformulation for the problem. We provide results of computational study that compares the conic formulation, Benders cuts approach and an alternative linear model. Compared to Benders Decomposition, MISOCP reformulation is easy to implement. We also observe that under certain experimental parameter settings, MISOCP reformulation outperforms others.

4 - The Product Line Design Problem with Social Network Effects

Dilek Gunnec, S. Raghavan

We model peer influence effects among the social network of users of products from the same product line. Influence among customers alters their utilities from the products, and therefore do not allow for an a priori preference ordering for an individual among different product profiles at the outset. We take into account product diffusion processes over the social network and identify the set of products to maximize the total market share when each customer selects the product with the highest utility. We construct a genetic algorithm to solve this computationally challenging combinatorial optimization problem to produce high-quality solutions.

■ TD-77

Tuesday, 14:30-16:00 - Collins Insight Institute

Behavioural OR and emergency planning

Stream: Behavioural Operational Research
Invited session
Chair: *Nikolaos Argyris*

1 - Face-to-face versus computer-mediated collaborative decision making processes: A scenario-based approach

Yasushi Sugimoto, K. Nadia Papamichail, Anita Greenhill

The aim of this study is firstly, to examine the feasibility of scenario-based decision-making exercises in crisis management settings, and secondly, to explore the role of digital technology in facilitating collaborative processes. The exercises of this research were conducted in the form of face-to-face (FTF) and online workshops in order to consider the differences between these two methods of communication. Comparisons were also drawn at the national level between the UK and Japan to investigate the influence of cultural elements on the participants' decisions and interactions. The results of this study showed that the exercises were beneficial for both British and Japanese participants regardless of the method of communication. However, several distinctive differences were found between FTF workshops and online workshops in terms of the discussion process and making decisions as a group. The findings had several implications and led to suggestions for further development of the scenario-based exercises. In particular, the findings suggested that a different strategy should be applied when designing FTF and computer-mediated exercises.

2 - The rôle of knowledge in risk identification and management: the 2014 Ebola outbreak

Navonil Mustafee, John Powell

Current approaches to risk management stress the need for dynamic (i.e. continuous, ongoing) approaches to risk identification as part of a planned resource application aimed at reducing the expected consequences of undesired outcomes for the object of the assessment. We contend that these approaches place insufficient emphasis on the system knowledge available to the assessor, particularly in respect of three related factors, namely the dynamic behaviour of the system under threat, the role of human agents and the knowledge availability to those agents. In this paper we address the rôle of knowledge use and availability in critical human activity systems (CHASs). We emphasize the distinction between information used within these systems

as distinct from the knowledge deployed by their human inhabitants. The aim of the paper is to offer a procedure for the mobilization of knowledge assets in the identification and management of risk within the system, building upon previous work which focused on the mobilization of knowledge about the system. We see knowledge as being a system asset, both deployed within and originating from system behaviour. Using the ongoing 2014 Ebola outbreak as an example, we offer a practical procedure for the identification of risks and appropriate policies for managing those risks.

3 - The behavior of violent crimes as an extension of property offenses in the world's most violent cities.
Thyago C. Nepomuceno, Ana Paula Costa

The determination of violent crimes, those related to citizens' lives, is viewed in this work as a function of property offenses, those related to public and private property, and in the function of law enforcement. We argue that the highest homicide rates in nine of the most violent cities of the world of 2014 are strongly correlated with high levels of impunity in suppressing crimes against property in the short term. We propose a mathematical model as a framework to explain this reality and use a monthly data of crimes, provided by non-governmental organizations, universities, and public safety departments of 9 jurisdictions around the world; we estimate the Spearman's rank correlation coefficient and cross elasticity measures of the crimes to support the model proposed. The misbehaving nature of data concerning criminality and the limitations of small sets of data available led to the usage of non-parametric approaches to determine a relationship of multiple variables that requires a distribution-free normality. Our results point to a negative relationship among the variables. The violent crimes in the current month were negatively correlated and statistically significant to the property crimes of a previous month in five cities, three of them Mexican and two Brazilian; and in four cities, one Brazilian city, two Hondurans, and one Guatemalan, the violent life-related crimes were negatively correlated to property misdemeanors, but were not statistically significant.

4 - Behavioural issues in nuclear emergency decision support
Nikolaos Argyris, Simon French

Many behavioural issues need to be considered by operational researchers, risk and decision analysts. In order to build a prescriptive analysis, they need to balance many factors in interacting with decision makers, experts and stakeholders. Further, behavioural issues also arise in modelling how different actors in a system may behave in different circumstances. We describe our experiences in designing decision support processes for nuclear emergency management, concentrating on the behavioural issues we have encountered and reflect particularly on the analyst's responsibility to address behavioural issues sensitively so as to lessen public stress. In doing so we distinguish between System 1 Societal Deliberation and System 2 Societal Deliberation which parallel that distinction between System 1 Thinking and System 2 Thinking in discussions of individual judgements and decision making.

■ TD-78
Tuesday, 14:30-16:00 - Architecture AR201, Level 2

Soft OR/PSM applications II

Stream: Soft OR and Problem Structuring Methods (contributed)
Contributed session
Chair: *Alberto Paucar-Caceres*

1 - Multimethodological Model for Strategic Planning of Municipal Governments with Problem Structuring Approach
Paloma Santos, Mischel Carmen N. Belderrain

Strategic planning of municipal governments, as well as unstructured problems, presents complexity due to multiple actors, conflicting views and uncertainties. In this paper is proposed a multimethodological model of strategic planning for municipal governments based on the SSP (Situational Strategic Planning) and methods of Soft Operational Research (SSM - Soft Systems Methodology and SCA - Strategic

Choice Approach). The proposed model follows the logic of the four SSP moments. In the Explicative moment, the use of the first three stages of SSM helps to understand and explain the problems. In Normative moment, the use of Design Mode of SCA relates goals to main issues and defines strategies. In the Strategic moment, the comparison mode of SCA evaluates the strategies according to previous criteria. An analysis of robustness of the strategies, considered high risk, is made through the use of scenarios. In Tactical-Operational moment is built an action plan for each strategy considering deadlines. The action plan is monitored both the implementation and the results. The model is an attempt to make government planning process more structured for policy makers.

2 - Soft systems thinking, methodology and the management of change
Kees van Haperen

Decision-makers within organisations don't allow themselves ample time for 'thinking'. Their executives often force them to follow the latest management fad without giving them time to determine what the true value would be for their organisation instead severely constricting them with corporacy and forcing the adoption of 'management straitjackets'. The authors acknowledge that more effort may need to be made to relate the thinking, and application of SSM, to the language used in many organisations. This is based on the basic distinction between 'what' and 'how' in problematic situations, and combines SSM with a range of other methods and techniques. In their forthcoming book the Authors present how, during the last 15 years, they have further developed SSM to 'add richness' which has proven to be an important ingredient to effecting organisational change across a wide range of central and local government organisations, commercial organisations and third sector organisations. In this paper, the Authors present an analysis of the case studies and associated conceptual models included in their book. This analysis will enable scholars and consultants to better understand the potential of the conceptual models and other modelling artefacts as 'reference frameworks' for change. The Authors will argue that the current paradigm in many contemporary organisations do not allow for sufficient time to think and plan.

■ TD-79
Tuesday, 14:30-16:00 - Architecture AR310, Level 3

Predicting Results in Sports

Stream: OR in Sports
Invited session
Chair: *Gerard Kuper*

1 - Predicting the NCAA Men's Postseason Basketball Poll More Accurately
John Trono, Philip Yates

A previous study investigated how well a linear model could predict where teams would be ranked in the final NCAA coaches' poll (for men's basketball) which is announced right after the post season, single elimination, championship tournament (known as March Madness) has concluded. Monte Carlo techniques were able to improve upon those results, which were obtained via a weighted, linear regression model. This Monte Carlo approach produced a model whose Spearman correlation coefficients were roughly equal to 0.85 for the top 15, top 25 and top 35 teams, respectively, with regards to said final poll. This article will describe a non-linear model that is approximately 10% more accurate than the previous model, and incorporates Zipf's law — and a quantity known as the Tournament Selection Ratio.

2 - Score Prediction using old databases in IPL cricket
Anay Rennie

Presently the projected score in 1st innings of a cricket match at a particular instant is calculated by taking run rates into consideration. The theory was not able to show the real picture as it failed to take into account the quality of the batting team, the quality of the bowling attack and the pitch conditions of the match. In my theory/model I have formulated a technique to calculate the projections using past records of the teams and ground conditions as parameters. The model is based on the database of all IPL matches played between the 8 regular teams since April 2008.

3 - Bias Estimation in Sports Predictive Models
Tom Flowerdew

Bias in predictive models is notable when the model's predictions are systematically different to observations. All statistical models will exhibit bias, originating from such sources as the omission of important input variables, selection bias in the training set, and other subject-specific examples.

This work presents a Bayesian framework in which to estimate a model's bias, specifically in the domain of sports modelling. The method will be extended to look at cases when the bias, and general modelling error become time-varying, and will then be used to investigate how bias presents itself in bookmaker's markets, and some common football prediction methods.

The purpose of this analysis is two-fold: in the short-term, knowledge of the nature of the bias occurring in model predictions would allow the model user to perform an ad hoc conversion to the outputs, to force the predictions to become unbiased. Preferably, the information collected from the proposed analysis would allow the model user to infer the cause of their model's erroneous predictions, and correct it accordingly.

4 - Using tennis rankings to predict performance in upcoming tournaments
Gerard Kuper, Gerard Sierksma, Frits Spieksma

To what extent is the position of a (tennis) player on a world ranking list (ATP for the men, and WTA for the women) related to his/her performance in an upcoming tournament? Can we reliably predict whether or not a (tennis) player makes it to, say, the quarterfinals of a Grand Slam tournament, knowing only his/her ranking on, say, two weeks before that tournament?

We show how to use ATP and WTA rankings to estimate the probability that a player with a certain ranking advances to a specific round (for instance, the quarterfinals) in an upcoming tournament. We use the results from Grand Slam and Olympic tournaments in the period 2004—2014. Pooling the data, which is justified according to our tests, allows us to compute probabilities with relatively small confidence intervals. For instance, the probability of a top 4 tennis player to reach the quarterfinals is 0.722 with a 95% confidence interval of (0.669; 0.771). This study was motivated by a request from the Dutch Olympic Committee (NOC*NSF). Based on our results, NOC*NSF decides which Dutch single tennis players to invite to participate at the 2016 Olympic Games of Rio de Janeiro.

■ TD-80

Tuesday, 14:30-16:00 - Architecture AR311, Level 3

Mathematical Methods of Economic Modelling

Stream: Mathematical Economics
Invited session
Chair: *Manuel Ruiz Galan*

1 - On Worst-Case Portfolio Optimization under Stochastic Interest Rate Risk
Tina Engler, Ralf Korn

We investigate the worst-case optimal investment strategy of an investor acting on a financial market under the threat of a market crash. The investor can invest both in a bond and in a stock. The interest rate of the bond is modeled as a Vasicek process, which is correlated with the stock price process. We adopt a non-probabilistic worst-case approach for the time and height of the market crash: While the stock price is driven by a linear stochastic differential equation before and after the crash, it loses an uncertain fraction of its value at the crash time. On a given finite time horizon, we then maximize the investor's expected utility of terminal wealth in the worst-case crash scenario. Our main result is an explicit characterization of the worst-case optimal investment strategy for the class of HARA (hyperbolic absolute risk aversion) utility functions.

2 - A Short Solution to the Many-Person Silent Duel
John Howard, Steve Alpern

The classical zero-sum 'silent duel' game was formulated and solved by researchers at RAND around 1948-1952. The story involved two antagonistic marksmen walking towards each other. A more friendly formulation has two equally skilled marksmen approaching targets at which they may silently fire at distances of their own choice. The probability of hitting the target decreases with its distance. The winner, who gets a unit prize, is the marksman who hits his target at the greatest distance; if both miss, they share the prize (each gets a 'consolation prize' of one half). More generally we can consider more than two marksmen and an arbitrary consolation prize. This non-constant sum game may be interpreted as a research tournament where the entrant who successfully solves the hardest problem wins the prize. We give a short and simple solution (entirely avoiding differential equations) to this game, and also give reasons why the form of the solution might have been anticipated.

3 - Representation Compatible Power Indices
Serguei Kaniovski, Sascha Kurz

We use average representations of a weighted voting game to obtain four new indices of voting power for this type of voting games. The average representations are computed from weight and representation polytopes defined by the set of winning and losing coalitions of the game.

These average representations come remarkably close to fulfilling the standard criteria for a coherent measure of voting power. They are symmetric, positive, efficient and strongly monotonic. The dummy property, which assigns zero power to powerless players, can be imposed by restricting the polytopes. The resulting restricted average representations are coherent measures of power.

Further properties can be imposed by tailoring the polytope. Restrictions based on the equivalence classes of voters defined by the Isbell desirability relation lead to another pair of power indices, which ascribe equal power to all members of an equivalence class. These indices are strictly monotonic in voting weight.

The defining property of the four new indices is representation compatibility, which ensures proportionality between power and weight. We believe that proportionality makes the new indices ideal measure of power for voting institutions, in which the votes are distributed to the voter based on their contribution to a fixed purse.

4 - Minimax Inequalities and Convexity
Manuel Ruiz Galan

Convexity —in the broad sense— is an essential assumption in most minimax theorems. We show how the so-called infsup-convexity, a not very restrictive notion of convexity that generalizes the classic convex-likeness, allows us to state a very general minimax result. In fact, a characterization of the minimax inequality is given in terms of this kind of convexity. For minimax inequalities of the Ky Fan-type, which strictly speaking are not minimax theorems, a new minimax inequality is established in terms of infsup-convexity, inequality that opens the way to new results on equilibrium problems.

References

● M. Ruiz Galán, An Intrinsic Notion of Convexity for Minimax, Journal of Convex Analysis 21 (2014), 1105—1139.

● M. Ruiz Galán, A Concave-Convex Ky Fan Minimax Inequality, to appear in Minimax Theory and its Applications 1 (2015).

● M. Ruiz Galán, Farkas Lemma in the Absence of Convexity and its Implications for Minimax Theory, submitted for publication.

■ TD-82

Tuesday, 14:30-16:00 - Architecture AR401b, Level 4

Strategy Analytics - Healthcare applications

Stream: Strategy and Analytics
Invited session
Chair: *Martin Kunc*

1 - Horizon 2035: Developing a long-term strategic vision for the health, social care and public health workforce in England

Matt Edwards, John Fellows, Siôn Cave, Graham Willis, Tom Lyscom

Horizon 2035 is a project commissioned by the UK Department of Health which takes a whole system view of the how challenges across the health and care system may unfold over the next 20 years in terms of demand and supply of wellbeing skills within the workforce.

Workforce in this programme has a broad definition that includes paid professionals such as doctors and nurses, as well as rarely considered informal workforces such as unpaid carers and volunteers.

A key success of the work has been to bring together expertise from across the system, including over 400 stakeholders across health, public health and social care to design multiple futures (using horizon scanning and scenarios).

The work has then simulated these futures using systems dynamics modelling to support policy analysis and aid robust decision making.

The CfWI's Robust Workforce Planning approach has been used for Horizon 2035, it combines system dynamics and systems thinking methods, enabling qualitative and quantitative analysis of future pressures on the English health and care system.

A key requirement of the project has been the explicit representation of uncertainty in the quantitative modelling as well as having practical outputs to support policy makers.

2 - System Dynamics and Big Data: Implications for Strategic Planning

Martin Kunc

System Dynamics is a simulation tool usually associated with the development and analysis of strategies. System Dynamics hasn't been considered a simulation that requires large amount of data. However, there are new trends in the use of System Dynamics and Big Data for the development and analysis of strategies. This paper discusses existing practices and proposes a new research agenda

3 - Optimizing statins reimbursement as a prevention strategic policy to chronic cardiovascular disease in Bulgaria

Rossen Kazakov, Penka Petrova

Statins are a group of medicines that keep the cholesterol levels down in healthy limits thus preventing patients to develop chronic cardiovascular disease (CVD). Designing and testing a prevention policy based on statins higher rate of reimbursement is the focus of this study, which uses data gathered by the Bulgarian National Health Insurance Fund /NHIF/ and market data by IMS Health. The needed data is plugged in a system dynamics model designed especially for the case, and a number of policy experimentations are conducted related to the following scenarios: 1/ a base case prevention policy based on 25% reimbursement of the statins group within the Positive Drug List by the NHIF; 2/ a prevention policy based on 50% reimbursement; 3/ a prevention policy based on 75% reimbursement; and 4/ a prevention policy based on 100% reimbursement. Additionally, two other factors are included in the model experimentation: 1/doctors' motivation to prescribe different percentage levels of cheaper generic medicines versus more expensive originator brands is included to experiment with and find the effect on drugs budget expenditure and the level of savings by using low cost medicinal treatment; and 2/ patients awareness about the medical and economic benefits of taking generic statins. Finally, an adequate prevention policy to chronic cardiac disease is proposed for implementation by the state reimbursement fund, accentuating on the need to increase generic medicines use.

■ TD-84

Tuesday, 14:30-16:00 - Architecture AR403, Level 4

Performance measurement and improvement in healthcare

Stream: Health Care Management
Invited session
Chair: *Laura Schang*
Chair: *Alec Morton*

1 - Treatment Planning Optimization for VMAT, Tomotherapy, and Cyberknife

Kerem Akartunali, Vicky Mak, Thu Tran

In this talk, we will discuss a unified mixed-integer programming model proposed in the recent paper of Akartunali et al. (2015), which simultaneously optimizes fluence weights and multi-leaf collimator (MLC) apertures in the treatment planning optimization and applicable to various machineries including VMAT, Tomotherapy, and CyberKnife. The model can incorporate all volume limits or dose upper bounds for organs- at-risk (OAR) and dose lower bounds for planning target volumes (PTV) either as hard constraints or soft constraints, depending on the user's preferences. We also propose several MIP heuristics as well as a meta-heuristic, and show that the meta-heuristic approach is very efficient for problem instances of clinical scale, capable of tackling a treatment field of 8000—64,000cm3, depending on the ratio of critical structure versus unspecified tissues. Finally, we conclude the talk with further research areas and their potentials in practice.

2 - Innovation in Healthcare Systems: A Socio-technical Perspective

Robert van der Meer, Colin Lindsay, Marion Bennie, Patricia Findlay, Emma Dunlop Corcoran, Johanna Commander, Norman Lannigan

We have investigated the large-scale automation of medicines distribution in NHS Greater Glasgow & Clyde, which is the largest regional health organisation in the UK. The pharmacy service is delivered on 14 hospital sites, involving approximately 530 pharmacy staff and an annual expenditure on medicines of around EUR 138 million.

The empirical evidence on the success of technological innovations in healthcare systems is decidedly mixed. There is considerable evidence on both theoretical and empirical grounds that the severity of implementation problems is likely to increase disproportionately with the scale and complexity of a healthcare technology installation.

A key finding from the initial stage of our research was that the introduction of new technology in healthcare may not only lead to unintended first-order consequences such as initial staff resistance, but can also generate potentially serious adverse feedback loops between the social and technical dimensions of the new system. A key finding from the second stage of the research is that the longer-term impact of new technology may be quite different for different groups of healthcare staff. New automated systems may free front-stage staff from more routine administrative activities, enabling them to spend more time directly with patients. On the other hand, back-stage staff may well find that their learning opportunities and promotion possibilities are curtailed as a result.

3 - Micro analysis of orthopaedic outpatient fracture pathway redesign

Gillian Anderson, Robert van der Meer, Alec Morton

The aim of this work was to retrospectively evaluate the redesign of the fracture pathway in a major NHS hospital, focusing on cost effectiveness at a micro level. The processes contain multiple points of variation at the input and at various stages throughout, which were considered in the evaluation. Discrete event simulation was used to model a major part of the re-design, a virtual fracture clinic, and the results compared with a model of a traditional clinic. Resource utilisation and cost was reported for each of the models. An important element of the costing was the family and patient resource or the societal cost of the re-design. This was evaluated using questionnaires to determine the number of clinic visits that patients make and the inconvenience this causes them in terms of time and out of pocket expenses. This work shows that there are savings from implementing the fracture redesign process, at least within the test hospital and from the perspective of health board and government funding. If this re design were to be rolled out further across Scotland it could result in significant effectiveness and efficiency savings. It is envisaged that the simulation model could be further used as a tool to support the process roll out to other hospitals across Scotland.

4 - A Decision Support System for Appointment Scheduling at a Public Hospital in Chile
Gabriela Fuenzalida, Sergio Maturana

One of the main problems faced by many Chilean public hospitals is the lack of enough specialists to meet the demand. This has generated very long waiting lists for many patients, which could mean an excessively long waiting time for some of them. Although the long term solution to this problem is to add more specialists, in the short term hospital have to assign priorities to the patients in the waiting list in order to make the best use of the existing specialists' time. We are currently developing deterministic and Markov Decision Process models to optimize the scheduling of patients. However, in order to be useful for the person in charge of scheduling, it is important that the information we use to drive the models is as current and correct as possible. Therefore we are also working on a Decision Support System (DSS) that will support the scheduling of appointments of patients who need to see a specialist using the deterministic and Markov Decision Process models and the most current data available. This system should be able to be used by people that do not possess a mathematical or computing background, and it should also be very flexible to handle unexpected events, such as patients that don't show up, or specialists that cannot attend patients for any reason. The DSS should also provide data that can be used to improve the service to the patients. We are also planning to use the same DSS for scheduling surgeries and other treatments.

Tuesday, 16:30-17:30

■ TE-01
Tuesday, 16:30-17:30 - Barony Great Hall

Plenary Lecture: Alan Wilson

Stream: Plenary, Keynote and Tutorial Sessions
Plenary session
Chair: *Tim Bedford*

1 - Solving Complex Problems for the Long Term: Cities in 2065
Sir Alan Wilson

The objective of this talk is to explore the challenges of complexity science within OR, illustrated by the current Foresight project on the 'Future of Cities in 2065'. Cities are archetypal nonlinear complex systems with the characteristic features of path dependence and the possibility of significant phase changes. The study of such systems for the long term involves OR handling challenges of interdependence and the development of large-scale models that can cope with high dimensionality. The models should be fully dynamic to allow for the explorations of future phase spaces. The approach of the Foresight project will be described: building evidence, recognising that long-term forecasting is impossible, but exploring future scenarios using an extended OR toolkit. The state of the science of urban modelling is reviewed, particularly given the aim of informing policy in the near future that will have long-term impacts.

Wednesday, 9:00-10:30

■ WA-01

Wednesday, 9:00-10:30 - Barony Great Hall

Keynote Lecture: Raimo P. Hämäläinen

Stream: Plenary, Keynote and Tutorial Sessions
Keynote session
Chair: *Gernot Tragler*

1 - Behavioural Operational Research
Raimo P. Hämäläinen

In this talk I will discuss the need for and recent developments in the emerging research area of Behavioral Operational Research (BOR). The goal of OR is to facilitate thinking and problem solving . How OR processes achieve this is one avenue of inquiry in BOR. What kinds of behavioral biases do OR methods themselves cause or solve is another. Behavioral issues are always present when supporting human problem solving by modeling. Behavioral effects can relate to the group interaction and communication when facilitating with OR models as well as to the possibility of procedural mistakes, cognitive biases and even to motivational issues. The research in BOR ranges from studies on how behaviour is captured in OR models to how to identify and avoid undesirable behavior effects. In this talk I will review themes and methods studied recently in this area. Although behavioural issues have been acknowledged by particular OR communities (e.g., decision analysis, system dynamics, game theory), much more behavioural studies are needed across the full spectrum of OR specialisms. We need to pay attention to behavioral issues as models are being increasingly used in addressing important problems like the climate change.

■ WA-02

Wednesday, 9:00-10:30 - Barony Bicentenary Hall

ROADEF/EURO OR Challenge presentation (III)

Stream: EURO Awards and Journals
Invited session
Chair: *Michele Quattrone*

1 - ROADEF OR Challenge presentation : Inventory Routing Problem at a glance with Air Liquide
Michele Quattrone, Jean André , Eric Bourreau, Marc Sevaux

The French OR Society (ROADEF) along with EURO, organizes periodically an OR challenge dedicated to industrial applications. This year, the challenge subject will be proposed by and industrial partner (AirLiquide) and will concern an Inventory Routing Problem. The challenge is open to everyone, and particularly to young researchers. The challenge problematic will be presented during this EURO 2015 and the results will be announced at EURO 2016 in Poznan. A prize of 20000 Euros will be awarded to the best teams. Contact: challenge@roadef.org

■ WA-03

Wednesday, 9:00-10:30 - TIC Auditorium A, Level 2

MAI: Speed networking 2

Stream: Making An Impact 1 (MAI 1)
Invited session
Chair: *Ramune Sabaniene*

1 - Speed networking: fast, fruitful and fun
Ramune Sabaniene

Networking as information exchange is not only essential to developing good professional practice, it is also an activity where we can all be givers. Generosity with one's own knowledge is the mark of a good professional.

EURO2015's 'Making an Impact' speed networking session gives a perfect opportunity to see how this works. It is designed so that even the shyest of us can join in without embarrassment. The outcome is an immediate boost to what you know about the world of OR practitioners, and to the number of people you may be able to turn to in the future — or who may be able to turn to you.

The session is designed so that you take part in a series of short focused meetings, introducing yourself to others and listening to what they have to say. You won't have time for long discussions — those can come later, over coffee or lunch — so make sure you are ready to spend a minute or so describing yourself and your interests. If you have business cards, bring them along to exchange; if you don't, we'll provide blank ones for you.

■ WA-04

Wednesday, 9:00-10:30 - TIC Auditorium B, Level 2

OR in Understanding Earth Science Data

Stream: Emerging Research and Applications of OR in Understanding Satellite, Climate, Weather and Earth Data
Invited session
Chair: *Gerhard-Wilhelm Weber*
Chair: *Emel Savku*

1 - Multicriteria Assessment of some Life-Cycle Industrial Materials within the Context of Sustainable Development and Energy Efficiency
Carlos Enrique Escobar-Toledo

On February 2011, the European Commission has adopted a new strategy to improve measures and access to raw materials, considering that EU is highly dependent of imports of them. The new strategy considers three pillars to improving raw materials' access. One of them is boosting resource efficiency and it promotes recycling. This paper contains a valuable methodology applicable to some materials' substitution based on Life Cycle Analysis. We consider that substitution is a multidisciplinary problem in nature dealing with Multicriteria decision making aid. The problem considers the role of energy use in sustainable development and the potential sources to increase energy efficiency during life cycle use of some materials used in a day to day basis. A set of criteria to make decisions for choosing alternative materials in the substitution process will be among other: Exergy loss, Green House Gases emissions, real energy flows and material balances needed to the chain of manufacturing processes in the production chain and the whole added value. Nevertheless, thinking in alternative materials to substitute the actual ones, it is necessary to look forward. That is why we will also use some other tools in order to complain a set of alternative materials for a long term use, as the prospective and systems dynamics techniques.

2 - Recent Applications of Applied Mathematics and Modern Continuous Optimization in Satellite Image Processing
Semih Kuter, Zuhal Akyurek , Ayse Özmen, Gerhard-Wilhelm Weber

Nonparametric regression and classification techniques are mostly the key data mining tools in explaining real life problems and natural phenomena where many effects often exhibit nonlinear behavior. In this talk, we will give a brief demonstration on the recent implementations of nonparametric regression splines supported by modern continuous optimization for the classification and atmospheric correction on satellite images, which have always been two hot topics for remote sensing community. First, we will represent an image classification approach on MODIS images for snow cover mapping by using Multivariate Adaptive Regression Splines (MARS). Second, we will introduce an application of atmospheric correction scheme on MODIS images by employing Conic Multivariate Adaptive Regression Splines (CMARS), which has been developed as an alternative method to

MARS by utilizing statistical learning, inverse problems and multiobjective optimization theories. The presentation ends with a conclusion and an outlook to future studies.

■ WA-06

Wednesday, 9:00-10:30 - TIC Lecture Theatre, Level 1

POM III

Stream: Production and Operations Management
Invited session
Chair: *Ali Ardalan*

1 - Multi Server Make-to-Stock Production Systems with Erlangian Processing Times and Several Demand Classes
Ozge Buyukdagli, Onder Bulut, Murat Fadiloglu

This study considers production control and stock rationing problem of a make-to-stock system with parallel production channels producing a single product demanded by different customer classes. If an arriving demand cannot be met, it is assumed to be lost. Two important decisions should be considered by decision maker: how many more channels should be activated and how the current inventory should be allocated among different customer classes. Today's advanced information technologies provide an easy access to current status of the production; therefore, searching for an optimal solution for these problems, which considers the age of the production, becomes more significant. For this reason, we model the system as make-to-stock queue where customer classes generate independent Poisson demands and the processing times are Erlangian (M/E_k/s make-to-stock queue). Erlangian processing times allow us not only to monitor system as frequent as needed by changing the value of k-parameter but also benefit from Markovian structure and corresponding MDP analysis techniques. These together with the flexibility of changing the value of the parameter s, the number of channels/servers, would allow us to depict the structural characteristics of optimal policies and to propose easy-to-apply and good-performing production and rationing policies compared to the ones widely studied in literature and used in practice for different settings.

2 - Control of a Multi-Server Make-to-Stock Production System with Setup Costs
Sinem Özkan, Onder Bulut

We study production and inventory control problems for an M/M/s make-to-stock queue with production setup costs, several customer classes and lost sales. We model and analyze the system using optimal control and dynamic programming techniques. At any system state, production decision is to specify whether to activate new production channels or to continue with the currently active ones. If the decision is to activate new channels, a fixed/setup cost is incurred per channel. At the decision epochs where the system experiences demand from any customer class, the controller should also decide whether to satisfy the arriving demand or to reject it. We extend the literature of the control of make-to-stock queues by considering fixed system costs and multiple servers at the same time. We first characterize the structure of the optimal production and rationing policies and propose new/alternative policies that have well-defined structures and are easier to apply compared to the optimal ones.

3 - Simulation experiments on using net requirements priority rule in JIT and CONWIP
Ali Ardalan, Rafael Diaz

This paper presents research related to a priority rule that is based on the concept of net requirements in Material Requirements Planning. The priority rule is used in JIT and CONWIP systems to determine the effect of measures of performance. Customer wait-time, total inventory, input and output stock-point inventories are performance measures. In almost all cases the use of the priority rule resulted in significantly shorter customer wait-time and a slight reduction in inventory.

4 - A robust optimization approach to production planning
Thomas Daniel van Pelt

In this paper we propose a robust optimization approach to single-item, multi-period, production planning in a rolling horizon setting when there is uncertainty in demand and production capacity. Mula et al. (2006) gives a comprehensive overview of production planning under uncertainty. However, any approach based on the work of Ben-Tal et al. (2009) is not to be found. Nevertheless, production problems are typically formulated as linear optimization problems and henceforth, a robust optimization approach lends its self very well. Furthermore, contemporary ERP systems that employ production planning do so in a rolling horizon setting and use linear optimization models. A simulation study is conducted to make a comparison between the nominal linear optimization problem, its robust counterpart in case of various uncertainty sets, its affinely adjustable robust counterpart and the best case were there is full knowledge on the demand.

■ WA-07

Wednesday, 9:00-10:30 - TIC Conference Room 1, Level 3

Engineering Optimization 1

Stream: Engineering Optimization
Invited session
Chair: *Wolfgang Achtziger*

1 - Stochastic Topology Design Optimization for Continuous Elastic Materials
Benjamin Ivorra, Miguel Carrasco, Angel Manuel Ramos

In this work, we develop a stochastic model for topology optimization. We find robust structures that minimize the compliance for a given main load having a stochastic behavior. We propose a model that takes into account the expected value of the compliance and its variance. We show that, similarly to the case of truss structures, these values can be computed with an equivalent deterministic approach and the stochastic model can be transformed into a nonlinear programming problem, reducing the complexity of this kind of problems. First, we obtain an explicit expression (at the continuous level) of the expected compliance and its variance, then we consider a numerical discretization (by using a finite element method) of this expression and finally we use an optimization algorithm. This approach allows solving design problems which include point, surface or volume loads with dependent or independent perturbations. We check the capacity of our formulation to generate structures that are robust to main loads and their perturbations by considering several 2D and 3D numerical examples. To this end, we analyze the behavior of our model by studying the impact on the optimized solutions of the expected-compliance and variance weight coefficients, the laws used to describe the random loads, the variance of the perturbations and the dependence/independence of the perturbations. Finally, the results are compared with similar ones found in the literature for a different modeling approach.

2 - On SAND Problem Formulations of Discrete/Discretized Structural Topology Optimization
Wolfgang Achtziger

We consider a class of classical problem formulations arising in the field of structural topology optimization and material optimization in discrete or discretized form. The central equations in these programs are the (usual) equilibrium conditions linking the control (resp. design) variables with the state variables. Standard approaches work with positive lower bounds on the design variables, i.e., in a framework of Nested Analysis and Design (NAND). In contrast to this, we consider problems without lower bounds formulated in both, control (resp. design) variables as well as state variables (Simultaneous Analysis and Design, "SAND"). By this, the stiffness matrix may well become singular (and typically is singular at an optimizer). This causes the breakdown of the usual constraint qualifications and of standard numerical solution algorithms etc. Nevertheless, certain continuity properties still can be proved to hold for the relation of control/design and state variables when the stiffness matrix becomes singular in the limit. These results can be used to prove that standard optimality conditions are satisfied at local optimizers provided the objective function of the problem has certain mathematical properties. These properties are satisfied for structural weight and for structural compliance, among others. Some results in this talk are based on joint work with Christoph Schürhoff.

3 - Large Scale PDE Optimization with the Feasible ArcInterior Point Algorithm (FAIPA)
Jose Herskovits

We consider nonlinear optimization problems with constraints involving partial differential equations (PDE) and solve them with an algorithm based on a limited memory quasi-Newton version of FAIPA, [1]. Given an initial feasible point, FAIPA produces a feasible descent sequence converging to a Karush-Kuhn-Tucker point of the problem. At each point, FAIPA defines a "feasible descent arc" and makes a line search along this arc to get a new interior point with a lower objective. To compute the arc, three linear systems with the same matrix must be solved. This matrix includes the quasi-Newton matrix and the constraints derivatives. We solve the linear systems iteratively, in such a way to avoid the storage of the systems matrix, of the quasi-Newton matrix and of the constraints derivatives. Only the calculus and storage of a directional derivatives of the constraints and of the gradient of an auxiliary function is required. Numerical tests for large scale applications in structural optimization with finite elements, show that the present approach is strong and efficient, requiring very small data storage.

[1] Herskovits, J., A Feasible Directions Interior Point Technique For Nonlinear Optimization, JOTA, Journal of Optimization Theory and Applications, London, v. 99, n. 1, p. 121-146, 1998.

■ WA-08
Wednesday, 9:00-10:30 - TIC Conference Room 2, Level 3

MAI: Data Science at work: practical experience from different applications

Stream: Making An Impact 3 (MAI 3)
Invited session
Chair: *Richard Weber*

1 - Data science at work: practical experience from different applications
Richard Weber

This workshop provides the opportunity to learn first-hand from several successful data science applications and interact with the respective project leaders. We will present a brief introduction to data science, focussing on its links to optimization, followed by several applications. Then the audience will have the opportunity to interact with the respective presenters, where we will share insights, pitfalls, and practical tips for each of the projects.

■ WA-09
Wednesday, 9:00-10:30 - TIC Conference Room 3, Level 3

MAI: Two workshops: Pro Bono O.R. and Using Government Data

Stream: Making An Impact 2 (MAI 2)
Invited session
Chair: *Felicity McLeister*

1 - The best thing the OR Society has done in years - one member's take on Pro Bono O.R.
Felicity McLeister

Come to this workshop to find out what Pro Bono O.R. is and what is so good about it. Skilled volunteering is on the rise and Pro Bono O.R. gives O.R. practitioners and academics the opportunity to put their skills to good use. The workshop will include an opportunity to discuss volunteer benefits, what you would like to get out of the scheme, barriers to volunteering, suggestions for improvement and more.

This workshop is for you if you are: UK practitioners/academics who might be interested in getting involved and would like to have more info about how the scheme works hear about the benefits; non-UK practitioners/academics who want to find out about our scheme and how they could adapt it for their own area; existing or past volunteers who want to come and share their experiences.

2 - Using Government data: opportunities and issues
Paul Randall

For many years successive Governments around the world have been providing open access to increasing volumes of data. The data has been used for a wide variety of purposes: from policy making to advocacy; from improvement programmes to evaluation. This workshop will examine: what is available; the uses to which OR practitioners can put that data; and the difficulties and limitations that are experienced in using official data. It will take UK government data as the initial example, and broaden out to international comparator data. Practitioners will be invited to reflect on their own experiences with, and possible future plans for, using national and international official data. The workshop is also intended for those with limited exposure to official data, but who are interested in the opportunities that it offers to practitioners.

■ WA-10
Wednesday, 9:00-10:30 - TIC Conference Room 4, Level 3

Food and agriculture supply chains

Stream: OR in Agriculture, Forestry and Fisheries
Invited session
Chair: *Sara Veronica Rodriguez-Sanchez*

1 - A retail site location decision process combining GIS and the AHP
Amparo Baviera-Puig, Norat Roig-Tierno, Juan Buitrago-Vera

The opening of a new establishment is a critical factor for firms in the retail sector. For this reason, it is crucial to perform a solid analysis of the possible locations for new store openings. This paper presents the development of a methodology for the process of selecting a retail site location that combines geographic information systems (GIS) and the analytical hierarchy process (AHP). First, we conduct an analysis of geodemand, which is used to locate the clients of a product or service. Second, geocompetition is analyzed, which means spatially locating the firm's competition. Third, the possible commercial sites are determined by combining the results of the two previous steps, together with the use of kernel density analysis. Finally, depending on the resources available to the firm, multi-criteria decision models are used to help select the best location from among the possibilities identified in the previous analysis steps. The AHP methodology shows that the success factors for a supermarket are related to its location and competition. To demonstrate its practical applications, the proposed retail site location decision process was applied in the Spanish city of Murcia to decide on the location for a new supermarket opening. The results obtained also included sales forecasts. It was possible because of the inclusion of an existing supermarket in the AHP process. Therefore, this methodology is an application of Operational Research in agribusiness.

2 - Building sustainable menus by means of goal programming
Javier Ribal, Gabriela Clemente, M. Loreto Fenollosa, Neus Sanjuan

Consumers are worried by the nutritional aspects of food and, as economic agents, also take into account its cost. Furthermore, there is a growing concern about the environmental effect of food production and consumption; studies show that between 15 and 30% of the total environmental impact caused by European consumption is brought about by the food sector. Due to the high degree of personal choice, food represents a good opportunity for consumers to influence their personal environmental impact. In line with the definition of sustainable diets from the FAO, this study develops a goal programming model to design a sustainable menu choosing out of a set of dishes considering nutritional, environmental and economic aspects. A case study is used to test the proposed model, specifically to design a weekly menu. Nutritional quality is assessed by means of the Nutrient Rich Food (NRF) index, the environmental aspects by the carbon footprint (CFP) and the economic aspects by the cost of the raw materials of each dish. Three goals based on reducing the average cost, average CFP and increasing the average NRF have been included in the goal programming. In order to obtain a balance between these, sometimes, competing objectives the Chebyshev variant has been used. The results make it possible to analyze the trade-offs between the three sustainability aspects taken into account and to quantify how budget restrictions can determine unhealthy or environmental unfriendly diets.

3 - Achieving beef self-sufficiency in Indonesia: Policy development using Agent Based Simulation
Stephan Onggo, Dhanan Utomo, Utomo Putro

Food security is a challenge to any developed country let alone to a developing country such as Indonesia. The Indonesian government has identified ten targets for food security which include beef self-sufficiency. Achieving beef sufficiency is important to Indonesia because it has become one of the largest beef importers in the world since 2010. One of the key challenges to achieve beef self-sufficiency is the non-conducive environment for a strong local production. The willingness of farmers to raise cattle and to increase their business scale depends on the expected profit and sales volume. The expected profit and sales volume are the direct result of the interactions between actors such as farmers and cattle traders. Hence, a study to understand the behaviour of various actors in beef supply chain is important. We have conducted a study to understand the interaction between farmers and cattle traders using observation and focus group discussion with the stakeholders in West Java. We use the findings from the study to develop and calibrate an agent-based simulation model. Experiments using the model uncover interaction patterns between agents (such as farmers and traders) which have some consequences on agents' access to the market, information passed between agents and the variation of supply and demand distributions. The results from the experiments have led to a number of ideas on policy intiatives that need to be evaluated in our future works.

4 - Production Planning in Pork Industry
Sara Veronica Rodriguez-Sanchez, Victor M. Albornoz

This paper addresses the production planning problem of a meat packing plant. Major decisions include the number of times each cutting pattern is applied on the available carcasses, the total yield per product and its corresponding levels of inventory at each time period. A mixed integer linear programming model is designed to face the problem. The main contribution is to maximize the total profit taking into account the variability of carcasses that forming the batch supplied. Moreover, a conceptual framework that identifies future directions and tools for enhancing theory and practice to improve pork supply chain efficiency is presented.

5 - Using multi-objective calibration techniques to assess impacts of climate change at farm level
Argyris Kanellopoulos, Pytrik Reidsma, Jacqueline Bloemhof, G.D.H. (Frits) Claassen

Assessing the impact of climate change on agricultural systems requires whole farm optimization models that can be used to simulate the behaviour of farmers and evaluate future adaptation strategies within scenarios of climate change. A good representation of the multi-objective nature of farmer's decision making is essential for accurate model predictions. Often in existing studies for reasons of simplification the multi-objective nature of the farmer's decision making is ignored and the existence of a single economic objective that drives the decision making process is assumed. In these studies, calibration techniques like Positive Mathematical Programming are used to recover unknown parameters of a non-linear cost function based on historical decisions. However, the existence of multiple objectives in farmers decision making is ignored which might affect the predictive capacity of whole farm optimization models. We use a novel multi-objective calibration technique to recover the unknown parameters of a non-linear Compromise Programming model. The proposed calibration method accounts for multiple conflicting objectives, improves the predictive capacity of the model and relaxes assumptions underlying the calibration process. We apply the calibrated model to evaluate the impact of climate change scenarios and future adaptation strategies of arable farmers in the Netherlands.

1 - Direct and Indirect Sales of National and Store Brands in a Manufacturer-Retailer Dyad: Pricing and Advertising Decisions
Nivedita Haldar, Sanjeet Singh, Abhishek Chakraborty

The paper explores the typical situation where a national brand manufacturer is selling through both its exclusive factory outlet and a multibrand retailer. The retailer on the other hand, is not only selling the national brand, but is also selling its own store brand. Hence the manufacturer-retailer dyad are involved in both Stackelberg and Bertrand games, being cooperative and competitive at the same time. The paper finds the optimal wholesale price of the national brand and the optimal retail prices of both the national brand and the competitive store brand. The paper also finds the optimal advertising expenses to be incurred by both the national and store brand manufacturers. The optimal solutions are obtained for a single manufacturing cycle, in which the setup costs, per unit manufacturing costs, transportation costs are taken as constants. Also, the consumer demand is taken to be deterministic and linear in retail prices and advertising expenses. The price elasticities are taken to be constants for the product and so are same for both the brands for the manufacturing cycle. The optimal solutions are obtained through solving bilevel programming problems for two separate cases: keeping the manufacturer as the leader and the retailer as the follower in one case and the reverse in the other. Then the results have been compared with a vertical-Nash game between the manufacturer and the retailer.

2 - Dynamic Cooperative Advertising in a Supply Chain
Zhimin Huang, Susan Li

In the literature on cooperative (co-op) advertising, the focus of research is on a single period relationship between a manufacturer and retailers in which the manufacturer is the leader and retailers are followers. Recent market structure reviews have shown a shift of retailing power from manufacturers to retailers. Retailers have equal or even greater power than a manufacturer when it comes to retailing decisions. Based on these observations, we intend to explore the dynamic role of co-op advertising with respect to transactions between a manufacturer and a retailer through brand name investments, local advertising expenditures, and participation and accrual rates. Our analyses are based on a dynamic two-stage game structure. At the first stage, the participation and accrual rates are determined. Then at the second stage, the manufacturer determines its brand name investment efforts and the retailer decides the local advertising levels to be spent. Two scenarios are discussed for the first stage of the game. In the first scenario, the manufacturer is assumed to determine the participation and accrual rates independently. In the second scenario, both the manufacturer and the retailer jointly determine the participation and accrual rates. We examine the effect of system dynamics on the behavior of the manufacturer and the retailer from the first scenario as well as the second scenario. Managerial implications of all dynamic results are discussed.

3 - Dynamic Innovation and Pricing Decisions in a Supply Chain
Anshuman Chutani, Alexandre Dolgui

This paper integrates the dynamic innovation and pricing decisions in a two-echelon supply chain. We model a distribution channel where a seller sells a product to an independent buyer who ultimately sells it to the customers. Both the players may put efforts over time to innovate and improve the quality and features of the product which in turn may enhance the goodwill of the product in the market. The innovation efforts may also be process focused and can affect the unit cost of production of the product. We assume that the product demand increases with goodwill and decreases with the retail price. We model the problem as a Stackelberg differential game in which the seller first announces its wholesale price and innovation efforts over time and the buyer responds by deciding the retail price and its innovation efforts over time. We obtain the feedback equilibrium strategies for a central decision maker in centralized channel, and for both the players in a decentralized channel. We also obtain some useful insights using numerical analysis.

■ **WA-15**
Wednesday, 9:00-10:30 - TIC Conference Room 6&7, Level 3

Pricing and Advertising

Stream: Supply Chain Management
Invited session
Chair: *Anshuman Chutani*

■ **WA-17**
Wednesday, 9:00-10:30 - TIC Conference Room A, Level 9

Supply Network Risk 1

Stream: Supply Network Risk and Resilience
Invited session
Chair: *John Quigley*

1 - Ranking Operational Performance of Suppliers with Variable Order Size

John Quigley, Mahdi Parsa, Lesley Walls, Nandakishore Aswathanarayana, Karsten Cox

Ranking can aid prioritisation to support effective allocation of management effort towards proactively mitigating the risk of non-supply. We develop a method for ranking Poisson count data with heterogeneous exposure to risk. Our study has been motivated by the challenge of assessing the performance of suppliers in terms of delivery timeliness and part quality when order sizes vary. Our method is based on empirical Bayes inference. We assume a two stage hierarchical model where suppliers form a pool for which events are generated from conditionally independent homogeneous Poisson processes and the event rate for each supplier is assumed drawn from a Gamma prior probability distribution. Deriving the probability distribution of the ranked event rate, allows summaries such as the mean ranks to be obtained. The distribution of the rank is analytically intractable and so we present approximation methods for obtaining both point and interval estimates of ranks. Using combined information about uncertainties arising due to variation in exposure and the sensitivity of a supplier's rank, the relative performance of suppliers can be estimated. An application of the proposed method is presented for a manufacturing industry case where we examine a portfolio of suppliers for a particular commodity to benchmark relative performance in terms of timeliness and quality. We illustrate how the findings can be communicated and discuss the implications for supply chain management.

2 - A Fuzzy Multi-objective Optimisation of Efficiency, Robustness and Resilience of Supply Networks

Dobrila Petrovic, Joanna Orzechowska

This paper presents a fuzzy multi objective optimisation model developed for a real world supply network. The problem is to determine how many components the manufacturer should order from suppliers and when in such a way as to satisfy customer demand. Two types of suppliers are available, standard, with longer lead times and smaller costs, and emergency with shorter lead times, but higher costs. Customer demand is forecasted and can be changed in terms of both required quantity and time until it is fixed. The objectives considered are network efficiency, robustness and resilience. Efficiency is measured as the total network cost. Different scenarios are considered when the customer fixed demand is for less, the same or more quantity, and it is required earlier, at the same time or later than forecasted. These linguistic terms are modelled using fuzzy sets. Robustness is measured as variance of costs incurred in all the scenarios. Resilience is measured in terms of shortage of required components, which has to be dealt with using emergency suppliers. Different tests have been conducted to analyse the impact of these objectives on the network performance. It is demonstrated that considering each or both of the objectives, namely robustness and resilience, in addition to the cost, increases the total cost. With respect to user preferences, each objective can be assigned different importance so that the degree of increase in the network cost can be reduced.

3 - Using Techniques From Network Science and Dynamical Systems to Determine Supply Network Sensitivity

Alan Champneys, Thilo Gross, Lars Rudolf

Predicting the response of large supply networks to external perturbation is a fundamental tool for risk management. With increasing complexity such predictions become challenging and require specific information, often not visible to a company. Here we show that not all components of such networks need to be measured equally well and present a technique for determining which are the most sensitive and influential components of the network.

The method relies on no detailed information on the product or information flows on the network other than its topology. Under the mild assumption of equilibrium conditions and in the limit of continuous flows, the method derives a system of ordinary differential equations with unknown parameters. Analytical numerical calculations are used to assign each component of the network a value that indicates its importance for the quality of any predictions.

The technique is illustrated on three manufacturing supply networks. The first involves a simple network, specific constructed to demonstrate key features of the method. The second is inspired by the food industry where there is a dynamic interplay between quality, reputation and price among different candidate suppliers. The final example is taken from a realistic representation of a whole industry with both inbound and out-bound supply chains. This final example example is used to illustrate how much information on sensitivity to

4 - Dual Sourcing Strategies Using Information on Disruption Discovery and Recovery

Thomas Archibald, Nurakmal Ahmad Mustaffa

This paper investigates how the information about supply disruption that is available to manufacturers affects the optimal sourcing strategy. A Markov decision process model of a single manufacturer with two suppliers is analysed under different assumptions about the information available on the occurrence of disruption and the length of recovery. The model also considers the impact of disruption to one supplier on the performance of the other supplier, an issue that is often overlooked in the literature. A comparison of the optimal policies under the various scenarios provides insight on the management of the disruptions to the supply chain.

■ WA-18

Wednesday, 9:00-10:30 - TIC Conference Room B, Level 9

Reverse Logistics and Manufacturing

Stream: Production and the Link with Supply Chains
Invited session
Chair: *Amin Chaabane*
Chair: *Alice Yalaoui*
Chair: *Erwin van der Laan*

1 - Remanufacturing Strategies under Carbon Tax

Zhaowei Miao, Yongquan Lan

With increasing concerns over environmental problems, remanufacturing is becoming an attractive production strategy for many forward-looking firms. We focus on remanufacturing strategies in the context of carbon tax to investigate how a firm considering remanufacturing strategies can optimize its price and quantity decisions under two different forms of carbon tax, that is, the unified carbon tax and the product-dependent carbon tax. We demonstrate that the attractiveness of remanufacturing is closely related to the types of the firm regarding its characteristics on production costs and emission efficiencies under both carbon tax policies. We provide several managerial insights through comparisons of remanufacturing conditions, emission performances, effects of tax changes on the profitability of the firm, consumer surplus, and social welfare under the two carbon tax policies. Our results provide useful insights for the policy makers to properly design carbon tax to reduce greenhouse gas emissions and to encourage remanufacturing.

2 - Analysis of Risk Pooling in a Risk-Adjusted Joint Optimization of a Hybrid Assemble- and Reassemble-to-Order System

Ebru Angun

In this talk, a multi-component, multi-product, periodic-review (re)assemble-to-order system is considered, which uses an independent base-stock policy for the inventory replenishment of the components. At the beginning of each period, end-of-lease cores are returned. Because the quality of cores is random, they are tested, graded, and sorted into four pre-specified quality levels. Then, the random, jointly and continuously distributed demands for the products are realized. In the problem, partial fulfillment is not allowed. Furthermore, the system quotes a predetermined response time window for each product, and it penalizes the system if the demand is not satisfied within its time window. This problem is modeled through a risk-adjusted two-stage stochastic programming problem, where the first-stage decisions are the base-stock levels for all components, and the second-stage decisions are the allocations of components to different products. The risk adjustment is achieved through a coherent risk measure. The resulting problem is solved for varying degrees of risk pooling.

3 - The Impact of Secondary Resale Markets on the Potential of Refurbishing

Erwin van der Laan, Niels Agatz

Manufacturers may choose to collect end-of-use products to deter cannibalization from the second-hand market or to potentially refurbish and sell them at a reduced price alongside their new products. The rise of the second-hand market for electronics online has an important impact on these decisions. In this paper, we model the pricing, collection and refurbishment decisions of an original equipment manufacturer in the electronics market in face of competition from a secondary resale

market. We show that an increased competition of the second-hand market provides an additional stimulus for manufacturers to collect and refurbish their products. In particular, we show that in some settings with competition from the second-hand market, it is beneficial to collect more than strictly necessary to supply the refurbishment operations.

■ WA-24

Wednesday, 9:00-10:30 - John Anderson JA3.25 Lecture Theatre

MCDM software

Stream: MCDM
Invited session
Chair: *Irene Abi-Zeid*

1 - ChemDecide — a MCDA software for the Chemical-Using Industries
Richard Hodgett

ChemDecide is a suite of software tools which incorporates three Multi-Criteria Decision Analysis (MCDA) techniques: Analytical Hierarchy Process (AHP), Multi-Attribute Range Evaluations (MARE) and ELimination Et Choix Traduisant la REalité trois (ELECTRE III). The software has been used for addressing decisions such as route selection, equipment selection, resource allocation, financial budgeting and project prioritisation by companies such as AstraZeneca, Proctor and Gamble, Pfizer, Fujifilm and GlaxoSmithKline. This presentation will showcase the ChemDecide software and demonstrate how it has been used by GlaxoSmithKline for the selection of a degasification technology for a new chemical development process.

2 - M-MACBETH for Multicriteria Resource Allocation
Teresa Cipriano Rodrigues, Carlos Bana e Costa, João Bana e Costa, Jean-Marie De Corte, Jean-Claude Vansnick

The M-MACBETH DSS (www.m-macbeth.com) implements the MACBETH approach to evaluate projects on multiple criteria base only on qualitative pairwise comparison judgements about difference of attractiveness. This multicriteria decision aid tool supports the selection of a good/best project. However, in a context of scarce resources, choosing a portfolio of projects is a more demanding problem, as it requires not only to balance benefits against costs and the risks of realising the benefits, but also to evaluate several projects together. There are several DSS for multicriteria portfolio analysis, that differ on the resource allocation procedure used: prioritizing projects by decreasing values of benefit-to-cost ratios or identifying the optimal portfolio by mathematical programming. It is well-known that the portfolios arising from the approaches do not always coincide, therefore it would be useful to combine both approaches, but few DSS do so. Within this framework, a new resource allocation component of the M-MACBETH DSS was developed, which implements the two approaches interactively. One distinctive feature is the ability to explicitly address the baseline problem, by sensitivity analysis of the stability of priority ranking and of the optimal portfolio. Besides, it is possible to deal with other constraints than the budget limitation, such as to force the inclusion or exclusion of projects from the portfolio or to model the mutually exclusion between projects.

3 - MCDA-ULaval : A multicriteria software for outranking methods
Irene Abi-Zeid, Nicolas Couture-Grenier

In this talk, we present MCDA-ULaval, a multicriteria decision analysis software for ranking and sorting, developed at Laval University, Quebec, Canada. The tool, designed with ease of use in mind, is programmed in Java, which makes it easily portable. MCDA-ULaval implements a subset of the ELECTRE outranking methods proposed by Bernard Roy and his collaborators. The methods currently available include ELECTRE III (for ranking), and ELECTRE Tri B, ELECTRE Tri-C, ELECTRE Tri-nC (for sorting). Variable thresholds are implemented for cardinal and ordinal criteria and a version of ELECTRE III with interaction between the criteria is also included. Furthermore, sensitivity analysis and stability/robustness/scenario analysis are among the features available.

MCDA-ULaval comes with a user guide and a few projects based on examples taken from the literature. The software is available for download at no charge, for research and teaching purposes, at: http://cersvr1.fsa.ulaval.ca/mcda/

4 - Visual PROMETHEE 2 - A new PROMETHEE software
Bertrand Mareschal

The PROMETHEE multicriteria decision aid methods are among the most used methods. This can be attributed to their intrinsic characteristics but also to the availability of user-friendly interactive software. After PROMCALC in the 1990's and Decision Lab in the 2000s, Visual PROMETHEE has been introduced in the 2010s. In this paper we present the new version of Visual PROMETHEE that includes many new features. It is the first PROMETHEE software that is available for multiple platforms (including Windows and OS X systems). The problem modeling and data management has been improved with a.o. new types of criteria and. The various visual analyses have been revisited to improve their readability and new types of PROMETHEE analyses are proposed including a complete sort method and a dynamic (time-dependent) extension.

■ WA-25

Wednesday, 9:00-10:30 - John Anderson JA3.14 Lecture Theatre

Product Design in Closed-loop Supply Chains

Stream: Environmental Sustainability in Supply Chains
Invited session
Chair: *Marc Reimann*

1 - The Effect of Environmental Regulation on DfE Innovation: Assessing Social Cost in Primary and Secondary Markets
Gal Raz

In this paper we study the interaction of environmental regulation, secondary markets and a firm's environmentally-focused innovation to capture their impact on the firm's economic, social, and environmental outcomes. We analyze a profit-maximizing firm manufacturing new products, selling them in a primary market in a developed country, and refurbishing some at the end of the first use stage to sell in a secondary market located in a developing country. The firm determines its design efforts for the use and end-of-life stages, its pricing in the primary and secondary markets, and its product collection rate. We assess the cost to society in the production, primary, and secondary markets under two regulation scenarios: 1) Extended Producer Responsibility (EPR), and 2) Minimum use stage efficiency. We apply our model to a data-based numerical study of cell phones and show that regulations can unintentionally worsen the overall social cost, although it may help to improve the per-unit relative social cost, a conclusion coinciding with recent papers discussing the interaction of absolute and relative decoupling of economic growth from resource use. We find that, for the case of cell phones, EPR leads to greater relative and absolute social costs than use stage regulation, but use stage regulation results in a higher investment in innovation. We also illustrate how regulation enacted in a primary market can impact the production and secondary markets.

2 - Managing Process Innovation for Remanufacturing in a Closed-loop Supply Chain
Yu Zhou, Yu Xiong

Remanufacturing is an opportunity to deliver all-round sustainability benefits. In this paper, we focus on remanufacturing at the level of the component, which can be performed by either the supplier or the manufacturer, and the supplier has the opportunity to lower the unit remanufacturing cost via process innovation. We find that, although the traditional manufacturing process accepts incremental improvement, remanufacturing requires radical innovation; in addition, inefficiency resulting from the decentralisation of decision in the closed-loop supply chain may lie in overinvestment in process innovation for remanufacturing. Our analytical results characterise the relationship between the optimal process innovation level and the optimal remanufacturing strategy, which reveals that the manufacturer may start up remanufacturing even if the supplier makes no investment in process innovation. Finally, our numerical analysis shows that letting the supplier remanufacturing could be a dominant strategy from the perspective of the manufacturer.

3 - Accurate response with refurbished consumer returns: Optimizing the return rate
Weihua Zhang, Marc Reimann

The optimal rate of returns is a key question associated with consumer returns. To account for the optimal choice of effort to reduce the return rate we extend our previous accurate response model and show how the optimal effort depends on the disposition possibilities associated with the consumer returns.

4 - Implications of Modular Designs: A Closed-Loop Supply Chain Perspective
Tina Wakolbinger, Thomas Nowak, Fuminori Toyasaki

Product modularity has become a well established concept for new product design that leads to accelerated product development and increases a company's abilities for mass customization. While effects of product modularity are very well investigated in forward supply chains, research only hesitantly began to analyze consumer as well as the reverse logistics implications of modular designs. This study explores the links between supply chain strategies with a company's optimal product design decision by considering reverse logistics operations. We study these relationships using two optimization problems, one for a company following a pull and one for a company following a push strategy. While in the pull model production decisions are delayed, leading to higher unit production costs, the push model is characterized by lower unit production costs but considers demand uncertainty by assuming a newsvendor setup. The results of our models highlight the importance of a product's lifetime duration and consumers' awareness towards modular-designed new or recovered products for making optimal product design decisions.

■ WA-26
Wednesday, 9:00-10:30 - John Anderson JA3.17 Lecture Theatre

Semi-Infinite Programming

Stream: Convex, Semi-Infinite and Semidefinite Optimization
Invited session
Chair: *Jan Schwientek*

1 - On the finite termination of an exchange method for nonlinear Semi-Infinite Programming problems
Soon-Yi Wu

We establish an explicit algorithm for solving nonlinear semi-infinite programming with polyhedron constraints. We propose a relaxed scheme by using an active set strategy. The relaxed algorithm does not require solving the global minimization problem over the metric space at each iteration, while it has only to find some points in the metric space such that a certain criterion is satisfied. A remarkable result is that the proposed algorithm terminates in a finite number of iterations for nonlinear SIP. Moreover, it is shown that the obtained solution at the final iteration is an approximate solution of the original problem. Numerical tests are provided on a collection of problems that have appeared in the literature. These numerical results indicate that the algorithm is more effective than many existing algorithms and the SIP solver fseminf in MATLAB toolbox.

2 - A transformation-based discretization method for solving general semi-infinite optimization problems
Jan Schwientek, Tobias Seidel, Karl-Heinz Kuefer

Discretization methods are commonly used for solving standard semi-infinite optimization (SIP) problems. The transfer of these techniques to the case of general semi-infinite optimization (GSIP) problems is difficult due to the variability of the infinite index set. On the other hand, under suitable conditions, a GSIP can be transferred into a SIP problem. However, this approach may destroy convexity in the lower level, which is of great importance for the design as well as the performance of numerical algorithms. We present a solution method for GSIPs with convex lower level problems, which cleverly combines the above mentioned two techniques. It can be shown that the convergence results of discretization methods for SIPs carry over to this approach under suitable assumptions on the transformation. Furthermore, we benchmark our method on a large set of test problems against the approach of transforming a GSIP into a SIP problem and solving the

latter one without the knowledge about the underlying GSIP by means of the Matlab routine fseminf as well as a discretization approach using a fine reference discretization. Finally, we demonstrate that our method solves small to medium-sized problems of maximal material utilization in gemstone cutting on a standard PC in reasonable time.

■ WA-27
Wednesday, 9:00-10:30 - John Anderson JA3.27, Level 3

Vector and Set-Valued Optimization II

Stream: Vector and Set-Valued Optimization
Invited session
Chair: *Marcin Studniarski*

1 - Nonconvex Nondifferentiable Multiobjective Programming Via the Vector Exact Exponential Penalty Function
Tadeusz Antczak

Most of the literature on the exact penalty function methods is devoted to the study of scalar convex optimization problems. In our considerations, we use the vector exact exponential penalty function method for solving a class of nonconvex nondifferentiable vector optimization problems. The most important property of this method is exactness of the penalization. Therefore, this property is examined for this method used for solving the considered nonconvex nondifferentiable multiobjective programming problem. Conditions are given guaranteeing the equivalence of the sets of (weak) Pareto optimal solutions of the considered nonconvex nondifferentiable multiobjective programming problem and its associated vector penalized optimization problem with the vector exact exponential penalty function.

2 - A General Framework for Multicriteria Descent Methods and a Characterization of the Efficient Frontier
Luis M. Graña Drummond

We present a general framework for some multiobjective optimization descent methods. The multicriteria steepest descent, the projected gradient and the Newton methods are all included in that framework. We also present extensions to the vector-valued setting of other classical methods for scalar optimization. Finally, we show that, in the convex case, a first order condition for efficiency (weak or not) allows us to characterize the optimal set.

3 - Higher-Order Conditions for Equilibria in a Discontinuous Gale Economic Model
Anna Michalak, Marcin Studniarski

In some economic models (see for example [1]) one has to consider discontinuous functions. We describe a simplified version of the Gale model [1]. The paper introduces the concept of strict local equilibrium of order k. The aim of this paper is to present higher-order necessary and sufficient conditions for strict local equilibria in the Gale model with discontinuous utility functions. This conditions are obtained by applying the results of [2] and are formulated in terms of generalized lower and upper directional derivatives of utility functions.

References [1] I. Bula, Discontinuous functions in Gale economic model, Math. Model. Anal. 8(2) (2003) 93—102. [2] M. Studniarski, Necessary and sufficient conditions for isolated local minima of nonsmooth functions, SIAM J. Control Optim. 24 (1986), 1044—1049.

4 - A New Scalarization Method for Two-Objective Optimization Problems
Marcin Studniarski, El-Desouky Rahmo

We propose a new scalarization method which consists in constructing, for a given two-objective optimization problem, a single scalarization function, whose global minimum points are exactly weak Pareto stationary points of the original problem. This equivalence holds globally and facilitates using evolutionary algorithms (for example, classical genetic algorithms with "roulette wheel" selection) to produce multiple solutions of the multiobjective problem.

◼ WA-28

Wednesday, 9:00-10:30 - John Anderson JA3.26, Level 3

Algorithms

Stream: Convex Optimization
Invited session
Chair: *Susana Scheimberg*

1 - A strongly time polynomial algorithm for the linear feasibility problem
Paulo Oliveira

A strongly time-polynomial algorithm for the strict homogeneous feasibility problem is presented. The number of iterations only depends on the error distance beteeen the solution and the current iteration. The overall arithmetic complexity is a cubic function of n and m, respectively the variable dimension and the number of inequalities. Additionaly, no matrix inversion is needed.

2 - Backward-Backward Splitting in Hadamard Spaces
Sebastian Banert

Based on an article of the author, a generalization of the classic backward-backward splitting scheme to metric spaces with nonpositive curvature is presented. In this setting, a regularization of the sum of two proper, convex and lower semicontinuous functions is minimized by evaluating their proximal mappings separately. Insights to an error-tolerant version of this algorithm are given.

3 - Inhomogeneous polynomial optimization over a convex set: An approximation approach
Zhening Li

We consider approximation methods for optimizing a multivariate inhomogeneous polynomial function over a general convex set. The algorithms are able to deal with optimization models with inhomogeneous polynomial objective functions in any fixed degrees. For a variety of the constraint sets, including the Euclidean sphere, hypercube, discrete hypercube, the intersection of co-centered ellipsoids, polynomial-time approximation algorithms with worst-case performance ratios are proposed. The homogeneous polynomial optimization counterparts are well studied in the literature, while the inhomogeneous polynomial models are rarely known. The approximation ratios of the proposed algorithms are in the same order (in terms of dimensions of the model) as its homogeneous polynomial optimization counterparts. Our methods can handle even more general sets, e.g., a polytope. Numerical results are reported, revealing good practical performance of the proposed algorithms for solving some randomly generated instances.

◼ WA-29

Wednesday, 9:00-10:30 - John Anderson JA4.12, Level 4

MINLP: recent developments and applications

Stream: Mixed-Integer Nonlinear Programming
Invited session
Chair: *Sonia Cafieri*

1 - A trust region method for solving grey-box mixed integer nonlinear problems.
Andrew Conn, Claudia D'Ambrosio, Leo Liberti, Delphine Sinoquet

We present theoretical and numerical results on a derivative free trust region method for mixed integer nonlinear problems with binary variables, which modifies the trust region by imposing local branching type constraints and cuts on the binary variables. The term grey-box in the title refers to the fact that some terms in the applications of interest to us, rather than being black-box, can be exploited directly in closed form. Preliminary results on simulation applications will be included

2 - Advances in multiparametric dynamic programming
Richard Oberdieck, Efstratios Pistikopoulos

Dynamic programming is a powerful methodology to solve optimization problems featuring multi-stage processes. It is based on the idea of decomposing the original problem into a series of stage-wise problems, each of which can be solved separately.

In recent years, multiparametric model predictive control (mp-MPC) has been established as a powerful tool in optimal multi-stage process control, as it solves the resulting optimization problem offline as a function of the state variables. Hence, the computational burden normally associated with online MPC is dramatically reduced as online optimization is avoided. However, the computational burden of the offline optimization required for the application of mp-MPC can be significant when more complex systems such as hybrid systems are considered. Hence, multiparametric dynamic programming has been proposed as a tool to reduce this computational effort.

In this paper, we report recent advances in the field of multiparametric dynamic programming. First, it is shown how the approaches previously presented in the literature follow the same modular structure. Then, a newly developed comparison technique is employed to avoid the formation of envelopes of solutions and thus retrieve the exact solution of the optimization problem. Lastly, computational evidence is presented that shows the viability of the novel techniques as well as provides guidelines for the use of multiparametric dynamic programming.

3 - Simultaneous Optimal Design of Materials and Sources Distribution of Electrical Thrusters
Satafa Sanogo, Frederic Messine

Electrical thrusters are devices used on spacecrafts to move satellites. They use electric energy to generate and accelerate some charged particles thanks to a coexistence of an electric field and a magnetic field produced by their magnetic circuits. In this paper, we address Topology Optimization methods based on a density approach to find optimal topology and shape of materials distribution and optimal values of sources distribution for the electromagnetic circuits of these engines. For such a problem, the design variables are material properties, which are discrete, and the current densities, which are continuous. Then, the problem is formulated as a Mixed Integer Nonlinear Program since the cost function and the constraints are non-linear. These design problems are difficult inverse ones. Indeed, they are Non Convex PDE-Constrained problems and ill-posed (in the sense of Hadamard) in general. In this work, we provide original methods to solve the considered design problem. Some numerical experiments validate the efficiency of our approach.

◼ WA-30

Wednesday, 9:00-10:30 - John Anderson JA5.02, Level 5

Reliability and Resilience

Stream: Simulation and Optimization
Invited session
Chair: *Bora Cekyay*

1 - Age Replacement Policies Dependent on Repair Times and Failure Times
Minjae Park, Gimun Jung, Dong Ho Park

This paper formulates a warranty cost model for the repairable products when an age replacement policy is adopted in cooperation with the renewing minimal repair-replacement warranty and studies the optimal choice of the preventive replacement age. Under the renewing minimal repair-replacement warranty, either minimal repair or replacement is performed depending on the length of repair time when the product failures occur during the warranty period. In this study, we develop the mathematical formulas to evaluate the long-run expected cost rates during the life cycle of the product under the proposed cost models and determine the optimal preventive replacement ages by minimizing the objective functions. Furthermore, the effects of the renewing warranty on the optimal preventive replacement age and its corresponding expected cost rate are investigated for various situations regarding the warranty policy. This study extends the existing results on the age replacement policy by considering more practical situations where both minimal repair and replacement are considered simultaneously upon

the product failures. Assuming that the product deteriorates with the age, we illustrate our proposed cost model and its optimization by numerical examples and observe the impact of relevant parameters on the optimal solutions regarding the preventive replacement age.

2 - An ILI Based Reliability Assessment of the Gas Pipeline With Corrosion Defects
Seong-Jun Kim, Byunghak Choe, Woosik Kim

Corrosion is a main cause of failures in the gas pipeline. Predicting pipeline failures as well as designing a maintenance plan plays a key role in effective use of energy and security of civil life. This paper deals with estimating the pipeline reliability in the presence of corrosion defects. Because a pipeline should be under uncertainty in its operation, a statistical approach called first-order reliability method (FORM) is adopted in this paper. A distinct feature of our method is to accommodate the stochastic character of corrosion growth and such feature is essential to obtain practical reliability estimations. Simulation experiments are conducted by using an in-line inspection (ILI) dataset. The result indicates that the proposed method works well and, in particular, it provides more advisory estimations on the pipeline reliability.

3 - Reliability Analysis Applied to an Automotive Industry
Amanda Mendes, Eliane Christo

Currently the quality is a key factor for any company because this search always meet the needs and desires of customers, since a quality product is a competitive product. The quality tools mentioned in the work are very important to achieve excellent products objectively that along with the reliability becomes possible to analyze in detail problems. Work will review data from a network of dealers occurred in vehicles failures within the warranty period and thus obtain possible causes of a problem related to a automotive window mechanism using of quality tools such as graphics to parts per million (PPM), which shows critical points in accordance with the manufacturing month, then the Pareto chart set up to establish priorities and the main fault effect. Having in hand the effect of failure is possible to construct a cause and effect diagram in order to look for possible causes that contribute to the effect found and subsequently with the aid of statistics and reliability will be possible to evaluate the probabilistic behavior of the problem through testing adhesion and reliability estimates of parameters from the running of vehicles and the costs related to repairs, making it possible to formulate forecasting models, assisting in decision-making regarding the maintenance of clientele's vehicles.

4 - Optimal Maintenance of Semi-Markov Missions
Bora Cekyay, Suleyman Ozekici

We analyze an optimal replacement problem of semi-Markov missions that are composed of phases with random sequence and durations. The mission process is the minimal semi-Markov process associated with a Markov renewal process. This implies that the phase durations are generally distributed and the successive phases of the mission follow a Markov chain. The system is a complex one consisting of non-identical components whose generally distributed lifetimes depend on the mission process. We prove some monotonicity properties for the optimal replacement policy.

■ WA-31
Wednesday, 9:00-10:30 - John Anderson JA5.04, Level 5

Algorithms and Applications

Stream: Algorithms and Computational Optimization
Invited session
Chair: *Alexandra Anderluh*

1 - A Fast Large Neighbourhood based Heuristic for the Two-Echelon Vehicle Routing Problem
Ulrich Breunig, Verena Schmid, Richard Hartl, Thibaut Vidal

In this paper we address an optimisation problem arising from city logistics. The focus lies on a two-level transportation system to deliver goods to customers within densely populated areas. The optimisation problem called the Two-Echelon Vehicle Routing Problem seeks to produce vehicle itineraries to deliver goods from a depot to customers

with transit through intermediate facilities. A local-search metaheuristic based on the principle of destroy and repair of a Large Neighbourhood Search is developed and implemented to find high quality solutions within limited computing time. For future reference we resolve confusion with inconsistent versions of benchmark instances by explaining their differences and provide all of them online. The proposed algorithm is tested with those instances. It is able to find the currently best known solutions or better ones for 95% of the benchmark instances. The computational experiments show that this simple method achieves excellent solutions for the problem within short computing times.

2 - Bimodal Synchronized Transportation for Inner City Freight Deliveries
Alexandra Anderluh, Teodor Gabriel Crainic, Vera Hemmelmayr, Pamela Nolz

Increasing urbanization combined with the looming threats of climate change constitute the current challenges in city logistics. Supplying citizens with all necessary goods without deteriorating the quality of life is difficult to accomplish. Therefore, we investigate the use of a more sustainable mode of transport, cargo bikes, in inner city delivery. We develop a two echelon routing scheme with synchronization of vans and cargo bikes. In our model the city is divided into three zones: the city center, the outer districts, and the so-called 'grey zone' marking the border between the city center and the outer districts. We investigate two different distribution policies and evaluate them according to the objective function comprising economic costs, emission costs and social costs, such as nuisance or traffic jam. The first policy is to assign all customers in the city center to cargo bikes and all customers in the outer-city districts to vans. In the second policy customers located in the 'grey zone' can be assigned either to vans or to cargo bikes while fulfilling all customer requests. A combination of heuristic and exact methods is used to solve this NP-hard problem. We are going to present preliminary results for a test instance from Vienna comparing the different distribution policies. These results illustrate the various kinds of costs and can therefore give planners a decision support in using such a more sustainable kind of freight distribution in a city.

3 - A Heuristic Method for the Periodic Inventory Routing Problem
Shu-Chu Liu, Ming-Che Lu

The periodic inventory routing problem is to determine the delivery routing and the inventory policies for retailers from a supplier in a periodic time based on the minimal cost criterion. Since it is a NP-hard problem, a heuristic method is needed for this problem. In the past, different global heuristic methods, such as tabu search, simulated annealing, have been proposed. However, they seem inefficient and ineffective. In this paper, a hybrid heuristic method for the periodic inventory routing problem is proposed. It integrates large neighborhood search (LNS) into particle swarm optimization(PSO) to avoid the drawback of trapped in the local optimality. The results show the proposed method is better than the existing methods in terms of total cost.

■ WA-32
Wednesday, 9:00-10:30 - John Anderson JA5.05, Level 5

Machine Learning and Its Applications

Stream: Machine Learning and Its Applications
Invited session
Chair: *Kristof Coussement*

1 - Multimodelling and Model Selection in Bank Credit Scoring
Alexander Aduenko, Vadim Strijov

The construction of a bank credit scoring model involves the selection a set of informative objects (client records) which are used for model parameters estimation. One has also to filter out redundant features which do not influence the outcome. However the object space can be clustered meaning that the importance of parameters can vary significantly across clusters. To get an unbiased estimate of default probability for each cluster one can use a separate model for each cluster. Separate model for each cluster can have low predictive ability in case the cluster is small and therefore posterior distribution of parameters has high variance. In such a case it is beneficial in terms of

predictive ability to select a biased model with lower variance to make predictions in small clusters. For model selection we suggest to use parameters prior and posterior distributions. A similarity function between distributions with known asymptotic distribution is introduced. This similarity function is compared to well-known similarity functions. The usage of suggested similarity function for model selection is illustrated with synthetic and real world datasets.

2 - A change detection model for association rules in education
Cheng-kui Huang

Adopting learning management systems to support teaching has become the norm in education field. Huge amount of data about the learning history of students thereby can been accumulated. In addition, educators can use data-mining techniques to evaluate students' learning performance. Association rule mining is one of the techniques used to study the correlation between teaching means or students' characteristics and their performance. For instance, the rule (Attendance.Low)(Gender.Male)(Semester.Middle) states that a student's semester grade is in Middle if his gender is male and attendance rate is Low, where Middle and Low are predetermined linguistic terms given by teachers. However, no studies have yet to assess changes by applying this type of rule in the realm of education. For instance, the above rule have been used to describe the students' behaviors on last semester, but, at the end of this semester, the rule changes to (Attendance.Middle)(Gender.Male)(Semester.Middle). To deal with this problem, this study proposes a change mining model to detect changes in students' learning performance.

3 - A Study on the Relation Between Plantar Pressure and Body Center of Gravity Using Back Propagation Neural Network
JongChen Chen

Feet play vital role, which affects our daily health and life. There are many reasons that might result in discomfort or pain in the foot. The purpose of this study is to investigate the relation between plantar pressures and center of gravity (COG). This study was implemented by moving the center of gravity in various directions and then examining its plantar pressure changes for each individual. A floor-based device (Bertec Corporation, Model BP 5050) was used for directing each subject to move his COG in a specific direction while wearing in-shoe sensor located on the force plate. BP was used as the classification tool. The result revealed that different leaning motions exhibited different pressure distributions, and that people tended to put their weights on the heads of metatarsal bones and hallux when leaning forward, on the heel when leaning backwards, and on one foot when leaning either to the left or to the right. Moreover, subjects had their own plantar pressure pattern, from which we could differentiate them to a certain extent.

4 - Identifying text mining adoption drivers
Kristof Coussement, Nathalie Demoulin

Organizations are nowadays overwhelmed with data characterized by its big volume, velocity and variety. Many information systems' researchers are proposing decision support systems built or enriched with textual information that originates from multiple resources. The use of text analytical methods is becoming inevitable. The purpose of text analytics is to derive high quality information from high volume of text collected through social media, call centers, etc. However, text analytics is not taking off sharply on the business side. Therefore, this paper investigates the drivers of text mining adoption. The conceptual model is an adaptation of the TAM2 to the specific case of text mining, including the tremendous importance of the information quality. The latter has been defined in various ways in the literature. We consider the characteristics of input data and output information as being determinants of perceived usefulness and perceived ease of use. In addition, our conceptual model includes two characteristics of the organization, i.e. customer orientation and top management support as being drivers of text mining adoption. To test our model, we conducted an online survey amongst 167 business analysts. We analyzed our data using structural equation modeling. Our results untangle the driving forces of text mining adoption. In the paper, we discuss managerial recommendations regarding text mining adoption as well as opportunities for future research.

■ WA-33
Wednesday, 9:00-10:30 - John Anderson JA5.06, Level 5

Multiobjective Optimization Methods for Renewable Energy and Sustainability

Stream: Multiobjective Optimization - Methods and Applications
Invited session
Chair: *Dylan Jones*

1 - A Goal Programming Methodology Applied to Planning of the Planting and Harvesting of Sugarcane
Helenice Florentino, Dylan Jones, Daniela Cantane, Chandra Irawan

The interest in sugarcane as a renewable energy source has recently been increasing worldwide. Therefore, the growing of sugarcane has been of increasing importance in recent years in several countries. These facts imply a need to produce large quantities of sugarcane and improve the quality of the resulting biomass to attend to the demand of the biofuels industry, which in turn requires a proper planning of the sugarcane crop cycle. It is often impossible for the manager of the mills to plan efficiently without the use of mathematical and computational tools. This is due to the great complexity and scale of the operations which also involve economic, social, environmental and political factors. Thus, generally an optimized planning in the sugarcane industry has a multiobjective character. The planning of planting and harvesting of the sugarcane is of great importance for the mills, because an effective schedule promotes a series of benefits throughout the cultivation cycle and in the subsequent industrial use. In this study we propose a multiobjective model that optimises sugarcane production of each plot, the date the sugarcane is planted, and the date it is to be harvested. The model uses goal programming strategies to ensure the date of harvest is always within the period of the maximum maturation of the sugarcane and considers the demands and other operational constraints of the processing mill.

2 - Assessment of the Suitability of Ports for Installation and Operations and Maintenance for the Offshore Wind Industry: An AHP Approach
Negar Akbari, Dylan Jones, Chandra Irawan

With the rapid development of the offshore wind industry, the role of ports in the supply chain becomes into spotlight. Ports serve the offshore wind industry as manufacturing, installation and operations and maintenance hubs and the growth in the size of the wind turbines imposes significant requirements on the ports in terms of their characteristics. As the offshore wind industry is relatively young, there exists a gap in the decision making tools in the industry for the determining the most suitable hub for the installation and operations and maintenance phases of the wind farm. In this study a number of candidate ports in the UK located on the North Sea coast have been selected and their suitability for acting as offshore wind installation and operations and maintenance bases for an offshore wind farm of about 500 MW capacity located in the North Sea is analysed by using the AHP (analytical hierarchy process) method. For this purpose, a number of input measures such as the port's layout, accessibility to transportation network, distance from the windfarm, port's depth, quay length and port's capacity, have been selected and the pairwise comparison data have been provided by a number of experts in the industry. Finally we show how the model is able to select the most suitable port from amongst a number of candidate ports as the installation or operations and maintenance base for the wind farm.

3 - Bi-objective Optimisation Model for Installation Scheduling in Offshore Wind Farms
Chandra Irawan, Dylan Jones, Djamila Ouelhadj

A bi-objective optimisation using a compromise programming approach is proposed for installation scheduling of an offshore wind farm. As the installation cost and the completion period of the installation are important aspects in the construction of an offshore wind farm, the proposed method is used to deal with those conflicting objectives. We develop a mathematical model using mixed integer linear programming (MILP) to determine the optimal installation schedule considering several constraints such as weather condition and the availability of vessels. We suggest two approaches to deal with the multi-objective installation scheduling problem, namely compromise programming with exact method and with a metaheuristic technique.

In the exact method the problem is solved by CPLEX whereas in the metaheuristic approach we propose Variable Neighbourhood Search (VNS). Moreover, greedy algorithms and a local search for solving the scheduling problem are introduced. Two generated datasets are used for testing our approaches. The computational experiments show that the proposed approaches produce interesting results.

4 - An Extended Goal Programming Methodology for Analysis of a Renewable Energy Network Encompassing Multiple Objectives and Stakeholders

Dylan Jones, Helenice Florentino, Daniela Cantane, Rogerio Antonio de Oliveira

This seminar proposes a goal programming methodology to ensure that a mix of balance and optimisation is achieved across a hierarchical decision network. The extended goal programming principle is used for this purpose. A model is constructed that provides consideration of balance and efficiency of multiple objectives and stakeholders at each network node and network level. A goal programming formulation to provide the decision that best meets the goals of the network is given. The methodology is demonstrated on an example pertaining to regional renewable energy generation and preliminary results are discussed. Preliminary conclusions are drawn as to the effect of different attitudes towards compensatory behaviour between objectives and stakeholders in the network. Connections to others concepts from different fields of Operational Research such as game theory and robustness optimisation are discussed.

■ WA-34

Wednesday, 9:00-10:30 - John Anderson JA5.07, Level 5

Emerging Applications on the Cloud 2

Stream: Emerging OR Applications on Cloud Computing
Invited session
Chair: *Vijay Naik*

1 - Service Composition Optimization in On-line Cloud Service Broker for Enterprise Environments

Vijay Naik

As cloud adoption in enterprise IT has increased, the number of providers of different types of cloud services has grown. This has created a new type of intermediary called Cloud Service Broker between service consumers and providers. Typically the Cloud Service Broker acts as an aggregator of same type of services from multiple providers. Increasingly the Cloud Service Broker is also being used for creating compositions using granular and heterogeneous services from multiple providers to fit the needs, minimize costs, meet performance guarantees, or to mitigate risks. To meet the requirements, the broker has to determine the set of services needed, find the matching service providers, and select service providers such that the overall objective is met. These composites involve life-cycle events including changes in capacity needs, failure recovery, and periodic updates for maintenance. Each such event involves revaluation of the objective function. In enterprise environments multiple lines-of-businesses have workloads with unique set of service dependencies. In addition, central IT and CIO may impose constraints on services consumed from different service providers. The Cloud Service Broker needs to be able to apply these constraints in an on-line manner, identify the qualifying service providers, and determine the optimal set of services. In this work, we describe how we model the service composition problem and describe a method to solve the problem in an on-line manner.

2 - Cloud Architecture of Traffic Mining Systems under Privacy Preservation

Hiroyuki Kawano

In Japan, there exist several independent traffic management systems, which have been developed by different expressway companies and organizations. These management systems partially exchange traffic data each other. During several decades, in order to increase the accuracy of traffic monitoring data, various devices and sensors have been developed, such as supersonic wave detectors, image sensors, ETC and others. Currently, it is becoming important to directly monitor traffic data by probe vehicles, including speed, acceleration, location, and

other attributes. In order to analyze traffic data dynamically, it is important to collect probe vehicle data widely and totally. But there are privacy issues to probe vehicle data, it is so hard to directly store data into traffic management systems on commercial public clouds. In this presentation, we propose a cloud architecture of traffic mining system under privacy preserving conditions. Secondly, we try to implement a prototype system of privacy preserving clouds by using CMS software and GPL software "HElib', which is a fully homomorphic encryption library in C++ and the NTL mathematical library. Finally, we evaluate performance of traffic data mining in our proposed cloud architecture. As a result, in the near future, different organizations will be able to exchange traffic data by using data cloud with privacy preservation.

■ WA-35

Wednesday, 9:00-10:30 - Colville C429, Level 4

Environmental Management

Stream: Energy/Environment and Climate (contributed)
Contributed session
Chair: *Andreas Welling*

1 - On the Optimal Number of Firms in a Polluting Oligopoly: A Differential Game with Open-loop and Linear Feedback Solutions

Andrea Mantovani

We revisit the dynamic Cournot game with polluting emissions from the standpoint of the well established discussion about the optimal number of firms in the commons. Taking into consideration access to the commons while leaving aside any other form of regulation of firms' behavior, we show that under linear feedback rules the industry structure which maximizes social welfare also minimizes the volume of emissions. This clearly does not apply under open-loop information. We then show that this coincidence cannot arise if the game involves the exploitation of a renewable natural resource.

2 - The Paradox Effects of Uncertainty and Flexibility on Investment in Renewables under Governmental Support

Andreas Welling

To optimally design or evaluate a governmental support scheme for renewable electricity projects it is decisive to consider the impact of the governmental support on the investment activity. Previous research on governmental support schemes has shown that in accordance to economic intuition and following the classical net present value decision rule, governmental support of renewable electricity makes investors to carry out more and bigger renewable electricity projects. Likewise, a decrease over time of the governmental support - for example a feed-in tariff - results in a lower capacity of renewables installed on a macroeconomic level. Under the assumption of at least slightly risk-averse investors, higher uncertainty also leads to a lower capacity installed. In this article, however, we show that these results are no longer valid under uncertainty, if companies do not only decide about the size of a renewable electricity project, but also have the flexibility to wait with the investment into the project. In particular, under uncertainty the investor's flexibility may lead to an optimal capacity of the project that does not depend on governmental support. Furthermore, decreasing fixed feed-in tariffs as well as higher uncertainty may - due to a lower option effect - lead to higher capacities of renewables installed on a macroeconomic level, at least on the short-run.

3 - Network Reductions Applied to Reliability Optimization Problems

Fábio Usberti

The reliability optimization of power distribution systems is an economically relevant field of investigation for the utilities. Many optimization techniques over real-life distribution networks can be impracticable due to the complexity of most reliability problems that are worth solving. This motivates reduction techniques that are able to obtain smaller but equivalent networks, without loss of optimality. A set of network reductions are presented and tested on real-life distribution networks. Proofs are given for the sufficiency of these reductions to obtain minimal networks.

4 - Elements for an Air Quality Management in the Metropolitan Valley of Puebla, Mexico
Maria A. Osorio-Lama, Victoria Haydee Romero Soto, Miguel Angel Valera Perez

Because air pollution is one of the most serious environmental problems, the need of effective environmental decisions applied to the Metropolitan Valley of Puebla in Mexico, is addressed in this paper. Decision support systems integrate appropriate data with conceptual models that include simulation, statistical tests and/or optimization. The state of Puebla is the fourth largest in Mexico, and the ZMVP is an important industrial zone with a population over 5 million of people. According to SEMARNAT, around 82% of emissions is generated by mobile sources, 15% by area sources and 3% by industry. The contribution of particles is less than 10 micros in 481 tons per year. Using a raw dataset from the most polluted area of the ZMVP and a processed dataset with data from the different stations in the region into a Relational Object Oriented Design framework, a multidimensional information process was used with OLAP (Online Analytical Processing) using ETL (Extraction, Transformation and Load) to manage the relational data stores

■ WA-36

Wednesday, 9:00-10:30 - Colville C430, Level 4

Ethics and OR 1

Stream: OR and Ethics
Invited session
Chair: *Erik Kropat*
Chair: *Katharina Burger*

1 - Richardson revisited
Giorgio Gallo

It s often said that OR has been originated by the military during WWII: the "Anti-Aircraft Command Research Group', better known as "Blackett's Circus', is considered as the first interdisciplinary OR research group. Actually, it can be argued that Richardson work, in the aftermath of WWI, aimed at analyzing via mathematical models the dynamics of conflicts, could be considered as an earlier example of OR. His work was motivated by a clear sense of ethics and by his strong pacifist feelings. Here we start discussing his "arms race' model, a model based on a system of linear differential equations, and show that, although quite simplistic, it can provide some interesting insights, in particular on the "liberal peace' idea. Thereafter, we present a new nonlinear system dynamics version of the model, and discuss the interesting insights on conflicts' escalation and de-escalation dynamics that can be derived from it.

2 - Identifying the Behavioural Influences on the Operation of Health and Social Waste Management: A Mixed Methods Study in the South West of England
Sean Manzi

Health and social care providers in the UK need to reduce the carbon footprint of their activities. Waste management (WM) is one aspect of the health and social care system that has been targeted for carbon footprint reduction. This system relies on a change to employee behaviour leading which has resulted in optimal and sustained change being difficult to achieve. This project sought to identify the behavioural factors influencing health and social care WM behaviour at four sites in the South West of England. The project used a mixed methods multistrategy concurrent triangulation design. Four studies (an interview study, an observational study, a waste audit and a questionnaire study) collected data about employee WM behaviours. The data from each study was analysed separately then the study findings were triangulated (interpreted in the context of each other) to produce a framework of behavioural factors acting on the WM system. The main findings from each study will be presented to demonstrate how complementing and conflicting findings can arise from studies of the same context highlighting the importance of data triangulation when studying complex behavioural systems. The resulting framework of behavioural factors will be presented and how studies such as those carried out in this project can inform the development of interventions and determining behavioural parameters for modelling and simulation.

3 - Impact of Occupational Commitment with Moderator Emotional Labor on Occupational Turnover in Field of Education
Zain Kiyani

Since 1980s the concepts of occupational commitment and occupational turnover have taken position of widely advocated topics. Many researches (Rhodes & Doering, 1983; Meyer, 1993; Blau et al., 2008) are done to explore the relationship of occupational commitment with occupational turnover and most of the times same results are concluded that show negative relationship between occupational commitment and occupational turnover. Present study is carried out to explore this relationship in field of education through different perspective that is moderating effect of emotional labor on this relationship. Emotional labor is taken as moderator in the study while the whole model is proposed to study in field of education particularly from engineering faculty. Faculty was divided in to two groups, i.e., entry level and advanced level. Results showed that Research Associates and Associate Professors are less on level on commitment that is further explained on basis on interviews.

4 - Theorising performative social affordances for collective action in problem structuring practice
Katharina Burger, Leroy White, Mike Yearworth

This paper seeks to contribute to the understanding of in situ dynamics in problem structuring interventions. Specifically, it addresses the need to understand how soft OR methods facilitate thinking and problem solving (Hämäläinen et al., 2013) in multi-organisational working (Ackermann et al., 2014) (White, 2009). An in-depth study of two succeeding stakeholder group modelling workshops was undertaken to understand performative dimensions of mediational structures in scaffolded interactions. Evaluation questionnaires were administered in the workshops, providing insight into socio-cognitive processes. This was complemented by video recordings of the participants in situ to enable an analysis of socio-ecological interactions. In the data analysis, three contextualist learning theories were employed. The analysis demonstrates how the three theoretical lenses may be applied to empirical data to view intermediate outcomes of PSM practice as processes of appropriation, transformation and co-creation, the sharing of appropriable tools for thinking, recognising interdependence and scaffolding positive emotional valence of collaborating as well as self-evaluative learning. This suggests that the micro-processes of sense-making and mangling (White et al., 2015) in problem structuring interventions may be seen as contributing to the participants' ability to create strategies in paradox (Clegg et al., 2002) through the dialectic resolutions of contradictions.

■ WA-37

Wednesday, 9:00-10:30 - Colville C411, Level 4

OR for Development and Developing Countries 3

Stream: OR for Development and Developing Countries
Invited session
Chair: *Youssef Masmoudi*
Chair: *Honora Smith*
Chair: *Andres Felipe Osorio*

1 - Queue Manangement in a Large Public Hospital of a Developing Country: an Application Using Data Envelopment Analysis
Komal Aqeel Safdar, Ali Emrouznejad, Prasanta Kumar Dey

Queuing is considered as a key efficiency criterion in any service industry, including Healthcare. Despite numerous Healthcare applications, Data Envelopment Analysis (DEA) has not been applied to evaluating queuing systems. Almost all queue management studies are dedicated to improving an existing Appointment System. In developing countries such as Pakistan, overloaded health systems, dearth of resources, and non-existent Appointment Systems result in extensive waiting times. The current study presents a novel application of DEA in evaluating the queuing process of a busy public hospital in Pakistan, where all patients are walk-in. The main aim of this paper is to demonstrate the usefulness of DEA modelling in developing a dynamic framework which alerts the hospital management of the moment to moment change in the patient inflow, so that appropriate measures

can be adopted. Among other factors, it was observed that inappropriate allocation of personnel is one of the main factors that affect the queuing situation. Therefore, an interactive framework is constructed which may assist the hospital management to quickly determine the required number of personnel at different wait times. Hence, the queuing situation is controlled pre-emptively, before wait times increase excessively. The proposed dynamic framework is generalizable and can be implemented in large public hospitals of other developing countries to continuously monitor and improve the rapidly changing queue situation.

2 - An Application of Artificial Neural Networks to Body Mass Index Estimation for Countries
Gözde Ergin, Gülhayat Gölbaşı Şimşek

Obesity is today among the most important health problems in many countries. Obesity is generally based on lean body mass to fat mass ratio increased as a result of excessive height which exceeds the desired level of body weight. There are a lot of factors which affect obesity. In this study, the use of artificial neural network in prediction of the country miss body index values is investigated. It is show that the estimation performance of artificial network gives consistent results in prediction.

3 - A Study on the Profitability of Family Farms in New Alta Paulista Region, São Paulo State, Brazil
Leonardo de Barros Pinto, Julianna Coracini Muchiuti, Gabriela Dezan dos Santos, Mauricio Endo Higuchi, Sandra Cristina de Oliveira

Sustainable development, generation of employment and income, food security and regional development, along with the search for efficiency, represent strong influence against the growing importance of family farming. In this context, there is the emergence of new exploration strategies and the development of new management models of family farms. The aim of this work was to examine the different ways of generating income of farmers in three municipalities of the New Alta Paulista region, and especially to identify the participation of farm and non-farm activities on family production systems. As a methodological analysis was used multiple linear regression, considering several independent variables (measuring the farm income and non-farm income of farmers in those municipalities), which could contribute to the constitution of the response variable, total gross income (TGI). The study showed that the variables: a) Total area of the farm, b) Ratio of farm income and total income, c) Ratio of total number of animals and area of the farm, d) Ratio of income earned through retirement and, or, pension and total income, and, e) Ratio of livestock income and total income, were considered the most significant variables (at level of 10%) for the constitution of the TGI.

4 - An Agent-Based Model Approach to Evaluating the Health and Economic Benefits of Public Financing of Epilepsy Treatment in India
Itamar Megiddo

Despite existing effective treatment, epilepsy is poorly recognized and treated globally. An estimated 6—10 million people in India live with active epilepsy, and less than half of them are treated. Several studies have shown that provision of first-line antiepileptic drugs (AEDs) in low- and middle-income countries, and specifically in South-Asia, is cost-effective. However, these studies have not evaluated the financial risk protection to patients and their households. We use an agent-based simulation model (with which we have previously published an evaluation on a rotavirus vaccine) of the Indian population and health system. We evaluate three scenarios of publicly financed epilepsy programs that provide first- and second-line AEDs and surgery. We find that though provision of first-line therapy can significantly reduce the disease burden and is cost-effective, it may not reduce financial risk. When considering care-seeking costs in addition to other direct costs, only providing first-line AEDs may even increase financial risk. A public finance policy that also provides second-line therapy provides financial risk protection to patients. An epilepsy surgery program similarly protects patients and is cost-effective, though it dramatically increases costs. These findings are important for India's plans for a nationwide epilepsy program.

■ WA-38
Wednesday, 9:00-10:30 - Colville C410, Level 4

Customer Based Services: Personalization, Interaction and Strategies

Stream: Customer Based Services: Personalization, Interaction and Strategies
Invited session
Chair: *Erdem Kilic*

1 - Customer Acquisition and Service Quality for a Call Center with Time-Varying Demand Response
Mojtaba Araghi, Philipp Afeche, Opher Baron

We study the problem of maximizing the profit of an inbound call center that controls periodic promotions with time-varying demand response, and service level to new and base customers during promotion periods. We propose and analyze a novel call center model that links these controls to customer flows, the size of the customer base and key performance measures. Our model considers the impact of service quality on customer acquisition and retention under time-varying demand response, and taking into account customer lifetime value. We provide prescriptions on optimal ad-hoc and periodic advertisement policies, along with the optimal staffing and priority plans for managing the call center operations.

2 - A Customer Selection Model based on Social Influence and Pricing Change in Social Network
Yingying Kang

Advertising is an important income for social network, which is growing fast and has created important impact on personal life and company campaign. Among various factors impacting advertisers' selection, pricing and social influence are two significant factors that influences the advertiser behavior directly. This paper introduces a new structured influence model to analyze the impact of social networks on advertiser decision and advertising behaviors. Analysis over two well-known social networks is presented. The results show the effectivity of the various factors of social networking, and the interrelations among those social network services.

3 - The Optimal Number of Rental Items to Own and to Borrow: A Bayesian Approach
Leonardo Epstein, Eduardo González-Császár

Inventory models for rental items may be used to plan service operations as diverse as rental of tools, access to telephone lines, or repair stations. The talk models the situation where the service provider owns a number of items that he rents-out, but these items may be insufficient to meet uncertain demand. When the inventory is insufficient, the provider may borrow, at a cost, additional items from another source. The purpose of the model is to determine the optimal number of service provider should own. We consider the situation where the number of users or clients is finite and takes advantage of information on client-specific rental history. Users may exhibit heterogeneous patterns of use that the approach incorporates explicitly. The Bayesian approach provides more appropriate measures of uncertainty for the Expected Present Value of the proyect than the standard approaches. Furthermore, it incorporates uncertainty form different sources: heterogeneity among subject-specific rental durations and times between consecutive requests for items.

■ WA-39
Wednesday, 9:00-10:30 - Colville C405, Level 4

Preference Learning I

Stream: Preference Learning
Invited session
Chair: *Krzysztof Dembczynski*

1 - Mining Ranking Models from (Dynamic) Network Data
Michelangelo Ceci, Donato Malerba

In recent years, improvement in ubiquitous technologies and sensor networks have motivated the application of data mining techniques to network organized data. Network data describe entities represented by nodes, which may be connected with (related to) each other by edges. Many network datasets are characterized by a form of (relational/network) autocorrelation where the value of a variable at a given node depends on the values of variables at the nodes it is connected with. This phenomenon is a direct violation of the assumption that data are independently and identically distributed (i.i.d.). At the same time, it offers the unique opportunity to improve the performance of predictive models on network data, as inferences about one entity can be used to improve inferences about related entities. In this talk, we propose a method for learning to rank from network data, also when the network may change over time.

2 - Ranking from Pairwise Preferences: The Role of the Pairwise Preference Matrix
Arun Rajkumar

Ranking from pairwise comparisons has gained a lot of interest recently.Given outcomes of pairwise comparisons among a set of items, the goal is to combine them into a global ranking over the items. Several algorithms including the spectral ranking, least squares, Matrix Borda, maximum likelihood under the Bradley-Terry model have been proposed for this problem. However, not much is known about when these algorithms perform well. We consider this problem under three settings. First, we consider a natural generative model where all pairs could be sampled and elucidate conditions under which these algorithms produce an optimal ranking that minimizes the pairwise disagreement error assuming the preferences are acyclic. We propose a SVM based algorithm that produces an optimal ranking under broader conditions than previous algorithms. Second, under the same model, we consider the setting where the preferences may contain cycles. Here finding an optimal ranking is in general NP-hard. We propose algorithms which rank 'winners' ahead of the rest, where the winners are based on tournament solutions. Third, we consider the setting where the number of items is large and one can sample only $O(n\log n)$ pairs. We propose the Low Rank Pairwise Ranking algorithm based on matrix completion ideas which produces an optimal ranking under broader conditions than previous algorithms. In each case, we obtain explicit sample complexity bounds and validate our theoretical findings using experiments.

3 - Monotonization of User Preferences
Peter Vojtas, Ladislav Peska

We consider instance ranking learning for a set of users on items represented by feature vectors (attribute values in the data cube). We say that an instance ranking (for a specific user) is monotonic if it is a monotone combination of score functions on domains of attributes (representing the degree of being ideal value of respective attribute). Monotonized preferences can be expressed as generalized annotated program rules and we have the Fagin-Lotem-Naor optimal threshold top-k algorithm.

We are interested in users for which it is hard to learn (monotonized) instance ranking. We consider the challenge of optimization between quality of learning threshold and minimization of set of users which are above the threshold.

Score functions transform preference on data cube instances to Pareto order preference cube. We consider the portion of unrepairable, indestructible and incomparable pairs as one of indicators of quality of monotonization learning.

We consider several further aspects of learning, e.g. implicit/explicit preference indicators, several metrics ranging from RMSE to order sensitive, different application domains, semantically rich/simple data.

We report on several experiments on public (also some conference competitions) and private data-sets.

4 - Indifference in volume-based methods for decision making under incomplete information
Rudolf Vetschera

Methods for decision making under incomplete information often deal with strict preferences between alternatives, but not with indifference. This also holds for volume-based methods like Stochastic Multiobjective Acceptability Analysis (SMAA), which calculates e.g. pairwise winning indices indicating the probability that an alternative is strictly preferred to another. However, indifference is an important concept for actual decision making.

In this paper, we extend previous research on deriving rankings of alternatives from the stochastic information provided by SMAA and similar methods to allow for indifference between alternatives. This not only requires a modification of the models used to obtain these rankings, but also an extension of the SMAA, where we introduce a pairwise indifference index analogously to the pairwise winning index. Since exact equality of utility values is unlikely to occur, this index is based on a notion of approximate indifference, and we discuss possible problems of intransitivity arising from this approximation.

We also present results from a computational study comparing rankings derived from different types of stochastic information (pairwise winning/indifference indices as well as rank acceptability indices), and also models allowing for indifference vs. models considering only strict preference.

◼ WA-41
Wednesday, 9:00-10:30 - Colville C512, Level 5

Preference Modelling I

Stream: Multiple Criteria Decision Aiding
Invited session
Chair: *Silvia Angilella*

1 - Robust Ordinal Regression and SMAA in Multiple Criteria Hierarchy Process for the Choquet Integral
Salvatore Corrente, Silvia Angilella, Salvatore Greco, Roman Slowinski

Interaction among criteria and hierarchical structure of criteria are two important issues of Multiple Criteria Decision Aiding. To deal with the interaction, fuzzy integrals are often used, in particular the Choquet integral. To handle the hierarchy of criteria, a recently proposed methodology, called Multiple Criteria Hierarchy Process (MCHP), can be used. While Robust Ordinal Regression (ROR) and Stochastic Multiobjective Acceptability Analysis (SMAA) have been already applied to estimate the capacities compatible with some preference information provided by the Decision Maker (DM), this paper aims at applying both of them to the Choquet integral as preference model in the case where the considered criteria have a hierarchical structure. To get a clear insight into the proposed methodology we shall apply it to a real world decision problem.

2 - Unleashing different mind-sets with the help of spanning trees approach
Sajid Siraj, Michele Lundy, Salvatore Greco

Pairwise comparison judgments often contain inconsistencies, and as this is generally considered undesirable, several methods have been proposed to measure and improve the level of consistency. However, rather than consider inconsistency as a problem, we view this as an opportunity to gain insights into different mind-sets that the decision maker may have. We propose a dimensionality reduction approach to offer all the spanning tree solutions to the decision maker as a visual aid for sensitivity analysis and/or revision of judgments. Finally, we demonstrate through examples why solutions from the eigenvector and geometric mean methods are not necessarily representative of any of these mind-sets.

3 - Axiomatic properties of inconsistency indices for pairwise comparisons
Matteo Brunelli, Michele Fedrizzi

The technique of pairwise comparisons is used by many decision making methods, as for example the analytic hierarchy process. Many inconsistency indices have been proposed in the literature to estimate the inconsistency of pairwise comparison matrices. We present and justify a set of properties necessary to define meaningful inconsistency indices. By proving their independence and logical consistency we are able to formulate them in the form of an axiomatic system. Furthermore, we shall check if existing indices satisfy the axioms and find out that, in fact, many do not.

4 - Rational Preference and Rationalizable Choice
Salvatore Greco, Alfio Giarlotta, Fabio Angelo Maccheroni, Massimo Marinacci

A decision maker (DM) is characterized by two binary relations. The first reflects the DM's judgments about his welfare and wellbeing, his (psychological) preference. The second describes the DM's choice behavior, his (revealed) choice. As argued by Mandler (2005), rationality requires that preference imply choice, that preference be transitive but not necessarily complete, and that choice be complete but not necessarily transitive. In the context of decision making under uncertainty, we propose axioms that aim at simultaneously describing the rationality of these two relations. These axioms allow their joint representation by a single set of probabilities and a single utility function. Specifically, it is rational to prefer f over g if and only if the expected utility of f is at least as high as that of g for all probabilities in the set; it is rational(izable) to choose f over g if and only if the expected utility of f is at least as high as that of g for some probability in the set. In other words, preference and choice admit, respectively, a representation à la Bewley (2002) and à la Lehrer and Teper (2011). Our results also provide a probabilistic foundation for a decision analysis procedure called robust ordinal regression, proposed by Greco, Mousseau, and Slowinski (2008), as well as for the associated structure called NaP-preference (necessary and possible preference).

■ WA-42

Wednesday, 9:00-10:30 - McCance MC301, Level 3

OR in Civil Government 3

Stream: OR in Civil Government
Invited session
Chair: *Vivienne Raven*

1 - Dynamic micro-simulation in the Department for Work and Pensions
Samuel Tazzyman

The Model Development Division (MDD) in the Department for Work and Pensions develops and maintains micro-simulation models, which are used to underpin forecasts and inform policy development. MDD has its own modelling engine, Genesis, on which a range of models are built covering pensions and working age benefits.

This presentation gives an overview of the Genesis modelling engine and how it makes a complex modelling process more accessible, meaning models are easier to develop and change. We then go on to give an overview of the main models; including some examples of their outputs and how they are used in government.

2 - Modelling & Measuring Labour Market Performance under Universal Credit
Ashley Buckner, Aidan Cross

Universal Credit (UC) is a new approach to working age benefits in Britain. By creating a single system for those in and out of work, Universal Credit is designed to ensure that work pays, and more work pays; and that claimants take more responsibility for finding work. It combines six existing benefits previously administered by the Department for Work and Pensions (DWP), Her Majesty's Revenue and Customs (HMRC) and Local Authorities into a single monthly payment administered by DWP. The first stage of UC began in April 2013: National roll-out is now underway. A typical claim to UC may encompass an individual moving in and out of work, to finally earning enough to leave UC. This is a departure from how DWP has previously measured labour market performance. Instead of measuring labour market performance as the proportion of claimants moving off benefit, performance needs to include extra dimensions of sustained employment and earnings progression. We will describe how we used elements of data science and statistics to ensure that the policy intent of UC was passed from Ministers down to front line staff. We will show how good data visualisation and spreadsheet design enabled us to impart complex performance stories to a largely non-analytical audience. We will also discuss how we used simulation to understand how the performance measures would react in different circumstances and how we used this to mitigate the shortcomings of the UC admin data.

3 - Mapping and Matching towards a Service Centre Transformation
Nicky Zachariou

The Department for Work and Pensions (DWP) is entrusted with the task of helping people lift themselves out of poverty through work, saving and support. DWP delivers crucial services to millions of people and makes reality Ministers' once in a generation welfare reforms whilst always trying to provide a greater value for money to the taxpayer. Universal Credit (UC) is the biggest welfare reform of recent years. It is a welfare benefit launched in the United Kingdom in 2013 to gradually replace all the working age means tested benefits including: Jobseeker's Allowance (JSA) and Employment and Support Allowance (ESA). The business as usual approach is applied to the current benefits with the need to always improve our services and do more with less, but with the added constraint of not interfering with the UC rollout. The decision was made to move towards a Service Centre (SC) format for JSA and ESA, which means the person answering the phone to take a claim is the person doing the benefit processing, or at least they belong to the same team. In the cases where a SC was not geographically viable, we tested a twinning approach, where a contact centre is matched to a benefit processing centre under single line management. Here, I will present a mapping tool used by the Operational Analysis Division to map out the DWP estates and a matching model for the different scenarios, which were both vital in the decision making of the service centre transformation.

4 - Forecasting and Discrete Event Simulation to support Border Force staff scheduling at the port of Calais
David Pavitt

UK Border Force performs immigration checks on all passengers travelling by ferry from Calais in France to Dover in the UK. Each year 10 million passengers and 2 million freight vehicles travel on this route. An appropriate number of immigration officers need to be deployed, in order to avoid vehicle queues building up disrupting the local area and causing passenger delays. At the same time, deploying too many officers would incur excessive staffing costs.

The Government Operational Research Service (GORS) has used a combination of forecasting and discrete event simulation techniques to build a staff scheduling tool for Border Force, which gives the appropriate staff deployment pattern across the day 6 weeks in advance.

■ WA-45

Wednesday, 9:00-10:30 - Graham Hills GH514 Lecture Theatre

Scheduling and Rescheduling

Stream: Optimization of Public Transport
Invited session
Chair: *Lucian Ionescu*

1 - Real-time High-Speed Train Rescheduling Incorporating Train Stop Deployment Planning in Case of A Complete Blockage
Shuguang Zhan, Leo Kroon

This paper aims at real-time train rescheduling while incorporating the train stop deployment planning on high speed railway lines in a large disrupted situation. In this case, a segment is completely blocked for a relatively long period of time. Due to the disruption, trains approaching the disrupted area have to be stopped at appropriate stations based on their types for both safety and operational reasons. The train stop deployment planning is applied to handle this problem during the disruption. We also reschedule trains for the whole day after the disruption. A mixed integer programming model is formulated to minimize the number of canceled trains and the total weighted train delay. Considering the uncertainty of the disruption, we assume that there is no anticipation on the occurrence of the disruption and a scenario-based rolling horizon approach is utilized to cope with the uncertain duration of the disruption. Besides, a column generation algorithm is used to solve our problem to optimality. By comparing the results obtained by these two approaches, we can evaluate the efficiency of the rolling horizon approach. The model is tested on a real-world instance of the Beijing-Shanghai high-speed railway while implicitly taking the related lines into account by cross-line trains.

2 - An exact formulation of the passenger-oriented train timetable rescheduling problem in case of severe disruptions

Stefan Binder, Yousef Maknoon, Michel Bierlaire

Delays are one of the major reasons for passenger dissatisfaction in the railway industry. Depending on the gravity of the delay, timetables, crew schedules or rolling stock may be affected. In this research, we address the issue of timetable recovery in case of severe disruptions. The recent scientific literature on recovery models mainly focuses on the operational point of view, thus paying less attention to the impact of passenger dissatisfaction in case of disruptions. These observations are the motivation for introducing a passenger-oriented methodology.

The exact formulation of the problem we present is adapted from the minimum cost flow problem and minimizes the overall passenger dissatisfaction as well as operational costs. Passengers' travel choices are represented by a path disutility function encompassing travel time, departure time shift and number of connections for every possible path between origin and destination. Computational experiments on a sample railway network inspired from real world data validate the model.

The number of passengers the exact model can handle is very limited. We therefore also propose an adaptive large neighborhood search metaheuristic that generates operationally feasible disposition timetables. A passenger assignment model evaluates the timetable and optimizes the latter in an iterative manner. The equivalence of both approaches is demonstrated on the sample network.

3 - Fast Heuristic Approaches to Solve the Multiple-Depot Vehicle Scheduling Problem

Denis Borenstein, William Progol Lopes, Pablo Guedes

The multi-depot vehicle scheduling problem (MDVSP) is a classical problem in operations research, arising in applications such as public transport systems. In this paper, a fast heuristic approach is proposed for solving the MDVSP. The heuristic is based on a two stage procedure. The first one applies state space reduction procedures towards reducing the problem complexity, based on the following criteria: (i) solutions of the single-depot vehicle scheduling for each depot; (ii) solution of a relaxed formulation of the MDVSP, in which a vehicle can finish its task sequence in a different depot from where it started; and (iii) a statistical criterion. Next, the reduced problem is solved by employing a modified truncated column generation approach. The approach has been implemented in several variants, through different combinations of the reduction procedures, and tested on a series of benchmark problems provided in the literature. The heuristic variants found solutions with very narrow gaps to best-known solutions, and outperformed the state-of-the-art methods in terms of computing time.

4 - Influential Factors on Robustness and Cost-efficiency of Resource Schedules in Public Transport and Airline Traffic

Lucian Ionescu, Bastian Amberg, Natalia Kliewer

Traditionally, the goal of resource scheduling, e.g. for crews and aircraft/vehicles is to minimize planned costs. However, in operations one frequently has to deal with disruptions which may lead to delays implying expensive recovery actions. This problem is addressed by robust resource scheduling when both planned cost-efficiency and robustness of schedules are considered as competing objectives. Therefore, a set of scheduling approaches is used to compute pareto-optimal solutions.

In this talk we aim at the generalization of findings from two research projects considering robust resource scheduling in public transport and airline scheduling. Therefore, problem characteristics in public transport and air traffic network topologies are examined and their influence on the degree of freedom for robust scheduling is discussed. Afterwards, we present several strategies that lead to an improvement of the pareto-front by improving the trade-off between robustness and cost-efficiency. This step includes the improvement of optimization techniques as well as a refinement of delay prediction models enabling a robustness evaluation closer to reality.

■ WA-47

Wednesday, 9:00-10:30 - Graham Hills GH513, Level 5

MAI: Making a real difference with the O.R. in Schools programme

Stream: Making An Impact 2 (MAI 2)
Invited session

Chair: *Charlene Timewell*

1 - Making a real difference with the O.R. in Schools programme

Charlene Timewell

O.R. practitioners... did you know that you could refine and develop your repertoire of skills by sharing your experience within the classroom? This exclusive workshop provides insight into one of The OR Society's key strategic projects: O.R. in Schools (ORiS), which promotes Operational Research to young people and their teachers in a bid to fulfil the Society's vision that "every school child knows what O.R. is'. Explore the vital role of an ORiS Volunteer, how they are supported by The OR Society, and the benefits they enjoy. Find out how O.R. practitioners from all backgrounds of experience across the UK are currently enthusing, inspiring, and motivating young people with demonstrations of and discussions about the applications of maths skills to solve real world problems and by opening their eyes to an array of career opportunities within O.R. Enjoy hands-on tasters of the most popular, interactive ORiS sessions and perhaps discover whether you have what it takes to make an impact upon the future of young people.

■ WA-48

Wednesday, 9:00-10:30 - Graham Hilils GH510, Level 5

Wireless Sensors

Stream: Telecommunication, Networks and Social Networks (contributed)
Contributed session
Chair: *Tugce Yucel*

1 - A Copy-At-The-Neighbor Multicopy Strategy for Improved Security Wireless Sensor Network

Tugce Yucel

A Wireless Sensor Network(WSN) is a collection of sensor nodes which are deployed randomly in an area for surveillance.Efficient utilization of limited battery energy of sensors for increased network lifetime as well as data security are major design objectives for WSN.Moreover secure transmission of data sensed to a base station for further processing.Producing multiple copies of data packets and sending them on different paths is one of the strategies for this purpose,which leads to redundant energy consumption and hence reduced network lifetime.In this work we develop a restricted multi-copy multipath strategy where data move through "frequently" or "heavily" used sensors is copied by the sensor incident to such central nodes and sent on node-disjoint paths.We develop a mixed integer programing(MIP) model and present some preleminary test results.

2 - Multi-base strategis to maximize lifetime in Wireless Sensor Networks

Eric Bourreau, Marc Sevaux

In our presentation, we consider the design of energy efficient operation schemes in wireless sensor networks in order to maximize network lifetime. We address target coverage with sensors used for sensing and sending data to a base station through multi-hop communication. With this purpose, a column generation algorithm exploiting a constraint programming approach based on graph variable and tree constraint is used to tackle the pricing subproblem and obtain optimal solutions. We generated on set of instances and analyse lifetime evolution of the associated networks. We investigate interest in a multi-base approach to reduce multi-hop communication (and then reduce battery consumption and then extend lifetime) with different positioning strategies. Benchmarks are available to experiment both optimisation and to tackle more realistic characteristics for the communication sensors.

■ WA-49

Wednesday, 9:00-10:30 - Graham Hills GH511, Level 5

Routing Applications in Urban Areas

Stream: Location, Logistics, Transportation (contributed)
Contributed session

Chair: *Kaj Holmberg*

1 - Heuristics for the weighted k-Chinese/rural postman problem with applications to urban snow removal
Kaj Holmberg

We describe a weighted version of the k-Chinese or k-rural postman problem that occurs in the context of snow removal. The problem concerns the questions of which vehicle shall do each task and how the vehicles shall travel between tasks. We also consider different numbers of vehicles, in view of a fixed cost for each vehicle. We describe and discuss heuristic solution approaches, based on usable substructures, such as Chinese/rural postman problems, meta-heuristics, k-means clustering and local search improvements by moving cycles. The methods have been implemented and tested on real life examples.

2 - Variable risk dependent on HAZMAT collection
German Paredes-Belmar, *Vladimir Marianov*, *Andres Bronfman*, *Guillermo Latorre-Núñez*

We present a new HAZMAT collection problem, in which a set of hazardous wastes are transported using a homogeneous truck fleet. The wastes can be transported in a same truck. The population exposed to an accident has a different type of risk, depending on the type of waste or waste combination in a truck. The risk to which the population is exposed by a truck load changes when a new type of waste with different risk is added to the truck. Furthermore, we consider the incompatibilities between different kinds of wastes. Using a bi-objective integer programming model, we minimize the total risk and transportation costs. We present a case study in the city of Santiago of Chile to show the practical application of our proposed approach.

3 - Logistic model for the multi-deliveries perishable goods
Grzegorz Pawlak, *Gaurav Singh*, *Malgorzata Sterna*

In the paper the solution for the practical distribution system for the perishable goods have been proposed. The problem is formulated as the simultaneous solution for the packing and vehicle routing problem with multi-deliveries. The practical constraints have been included into the model and the computational experiments have been proposed. The extension of the model is to introduce the drivers assignment to the fleet of the different trucks.

■ WA-50

Wednesday, 9:00-10:30 - Graham Hills GH512, Level 5

Optimization in Liner Shipping

Stream: Maritime Transportation
Invited session
Chair: *Berit Dangaard Brouer*

1 - Liner Shipping Cargo Allocation with Service Levels and Speed Optimization
Kevin Tierney, *Stefan Guericke*

We present a mixed integer model for the cargo allocation problem that arises in several different contexts in liner shipping, such as network design, speed optimization and empty container repositioning. We introduce service levels for transit time requirements to more realistically model cargo allocation. The maximum duration for each cargo flow is considered by leg dependent vessel speeds, transhipment operations as well as load dependent port call durations. This allows the analysis of the trade-off between service speed, transit times and bunker cost. We present results for transit time optimized networks on the Baltic, WAF and Mediterranean LINER-LIB instances. In addition, the trade-offs between transit times and bunker cost are analyzed in a case study that highlights the importance of considering the transit time to adjust or optimize liner networks.

2 - Liner Shipping Service Scheduling with Workshift Costs
Line Reinhardt

Container shipping companies are currently facing combined challenges of overcapacity and volatile fuel prices. In addition, rising concerns about greenhouse gas emissions has made it crucial for shipping companies to reduce their fuel consumption. The consumption of fuel for shipping vessel is polynomially proportional to the speed. This study proposes a new model which for a fixed liner shipping network, minimizes the fuel consumption by adjusting the port berth times to allow for a more even speed throughout the service and thus a lower overall fuel consumption. This speed optimization is done while ensuring that given transit time limits for the carried cargo is satisfied, and considering the layover time for containers transshipping between services. Workshift times and cost are included ensuring that changing the port visit time will not introduce an addition cost for the port operations. The model gives the global optimal solution for an entire network of container liner services and penalties for moving the port time is introduced to avoid the cumbersome work of changing port visit times when only negligible savings can be achieved. Preliminary results applying the model on real size liner shipping networks is presented.

3 - Joint Optimization of Speed and Buffer Times in Liner Shipping
Judith Mulder, *Willem van Jaarsveld*, *Rommert Dekker*

Liner shipping networks consist of fixed ship routes and time schedules that are published beforehand. However, delays are inevitable while executing the timetables, introducing uncertainty in sailing and port times. To maintain schedule reliability and reduce delay cost, liner companies will try to limit the amount of delay with respect to the schedule. Delays can for example be managed by adding buffer times in the timetables (prevention) or by increasing the sailing speed of the ship (recovery). Our goal is to jointly optimize the buffer times and sailing speed. Buffer time allocation is a problem on the tactical planning level, which has to be made in the scheduling problem before routes are executed. Adjusting the sailing speed, on the contrary, is a decision on the operational planning level. Hence, the optimal sailing times given a buffer allocation should already be available when determining the quality of the given buffer allocation, while in practice these decisions are taken much later. In our solution approach, we use that the optimal cost associated with a fixed buffer allocation can be obtained by solving a finite state Markov Decision Process and is convex in the buffer allocation. Hence, we can use a subgradient-based approach to find an optimal solution to the joint problem.

4 - The Cargo Composition Problem
Alberto Delgado, *Dario Pacino*, *Rune Jensen*

Containerization plays an important role in the battle for the reduction of CO2 emissions in international transportation. The more containers a vessel carries, the smaller is the resulting CO2 emissions per transported ton of cargo. This suggested focus on vessel intake maximization is old news for liner shippers. Stowage managers fight this battle daily. They are the planners of the cargo and have to find a load configuration that both suits the cargo to load in the current port and in addition guarantees that the vessel can be utilized to its maximum in future ports. The size of vessels nowadays, however, is making this work harder and harder. Moreover, the cargo composition available in the different ports might not be suitable for the full utilization of the vessel. To give a very brief example, consider a vessel that has to load a high number of very heavy containers. As a consequence the draft of the vessel will be greater. If the vessel has to visit a port with a lower draft limitation, stowage managers will have to leave a number of containers behind in order to reduce the draft. In this work we use vessel stowage models to analyse how well a composition of cargo fits the stowage characteristics of a containership. Moreover, we will present the first vessel stowage model to handle variable displacement. A series of experiments will be presented showing the performance of the model and e.g. it's improved accuracy as a revenue model.

■ WA-51

Wednesday, 9:00-10:30 - Graham Hills GH512, Level 5

Matheuristics for combinatorial optimization

Stream: Matheuristics
Invited session
Chair: *Vittorio Maniezzo*

1 - Matheuristics for offshore wind farms cable routing
Martina Fischetti , David Pisinger

A matheuristic approach is used to solve the inter-array cable optimization problem for offshore wind farms. The problem consists in finding an optimal cable route to connect all the turbines to one (or more) offshore substation(s). The model considers different constraints, such as cable capacity, prices, no crossings, a limited number of connections to each substation, and possible presence of obstacles in the site. First, a MILP model is defined. Even if it is well performing in general, in some particularly difficult instances it requires a large amount of time. Therefore we investigated three different matheuristics based on a relaxed version of the model. The heuristics developed are: - a random heuristic: we randomly fix some of the arcs of the current best solution and re-optimize the others using the MILP solver - a distance based heuristic: we randomly fix some of the arcs of the current best solution based on the distance to the substation(s) - a sector heuristic: we randomly decompose the problem into sectors, fixing the arcs outside the sector and re-optimize those inside Each of the three matheuristics has been tuned to find a proper trade-off between neighbourhood size and solution time. Finally, the different matheuristics are combined in order to define the best strategy to approach the overall optimization problem.

2 - Ng-relaxation based heuristics for large scale capacitated vehicle routing problems
Vittorio Maniezzo, Marco Antonio Boschetti, Elena Rocchi, Francesco Strappaveccia

Lower bounds based on the computation of ng sets have proven particularly effective when applied to capacitated vehicle routing problem (CVRP) instances. Such bounds have been studied in the framework of exact solution algorithms, but the building blocks of the bounds, as obtained from the internal state space relaxation recursion, can provide information also for constructing primal feasible solutions. While the CVRP bound is in fact obtained only at the end of a full column generation procedure, the dynamic programming algorithm at the core of this generation identifies structures, that can be of use for heuristic solutions. We conducted a study where we tried to include ng-sets, ng-paths and ng-routes in a heuristic solution generation procedure. Results will be presented on standard instances from the literature and on newly designed large scale instances. Commonly used large scale CVRP instances are in fact highly structured, and may introduce a bias when assessing the merits of different heuristic approaches, therefore we included in the testset several large instances derived from freight logistic actual practice.

3 - Branch-and-Price Based Matheuristics for a Vehicle Routing Problem with Time Windows and Variable Service Start Times
Hande Kucukaydin, Yasemin Arda, Yves Crama, Stefano Michelini

We investigate a vehicle routing problem with time windows (VRPTW), where the drivers are paid per time unit worked and the starting times of their shifts are to be determined by the decision maker. In order to solve the problem to optimality, a branch-and-price (BP) algorithm is implemented recognizing the pertinent pricing subproblem as an elementary shortest path problem with resource constraints (ESPPRC) which can handle an infinite number of labels and employs effective dominance rules. We present the past, present, and future implementations of the BP procedure based on bounded bi-directional search, decremental state space relaxation, and ng-route relaxation. We further discuss the design of BP-based matheuristics which make use of metaheuristics in pricing subproblem resolution, upper bound improvement, and column generation.

4 - Fill Rate Window as a Criterion for Spares Allocation
Yahel Giat, Michael Dreyfuss

The biggest problem for the successful adoption of electric cars is the frequent need to recharge the battery and the waiting time associated with it. One of the suggestions to overcome this problem is that carmakers retain ownership of batteries and provide service stations in which customers replace their depleted batteries with recharged batteries in lieu of waiting for their battery to recharge. Motivated by this approach, we consider spare allocation in an exchangeable-item multi-location repair system with Poisson arrivals and ample servers with general repair time distribution. Customers expect to be served within a certain time window and penalize the service provider if they have to wait more than that window of time. Accordingly, instead of minimizing average waiting time, we suggest that firms should consider maximizing the fill rate window, i.e. the probability that customers wait

less than a predetermined time window. We derive the entire system's fill rate window for any time window, and characterize its functional form. For each location the fill rate window can be either concave or S-shaped. We find upper and lower bounds to the optimal solution and characterize the cases for which the difference between the bound is zero. We complement the theory with a large scale numerical example motivated by the recent unsuccessful attempt to introduce electric cars into Israel.

■ WA-52
Wednesday, 9:00-10:30 - Graham Hills GH554, Level 5

Macroeconomic Factors and Investment Decisions

Stream: Financial and Commodities Modeling
Invited session
Chair: *Rita D'Ecclesia*

1 - Alternative Methods for Estimating Hedge Ratio. A Case Study of Foreign Stock Markets
George Kaimakamis , Alexandros Koulis, Christina Beneki

The present study examines parametric models called Autoregressive Conditional Density Estimation dels (ARCD) which, beyond the mean and variance, also permit time varying kurtosis and symmetry, and thus lead to estimating dynamic analogies of hedging. The question is whether the analogies stemming from an ARCD model lead to better hedging in comparison with analogies which are estimated through traditional econometric models such as the rdinary Least Square model (OLS) and the Error Correction model (ECM). The analysed sample consists of daily closing market rates of the stock market indexes of the USA, the UK, Germany, and Japan, as well as the equivalent futures contracts. The findings indicate that the time varying hedge ratios, if estimated through the ARCD model, are more efficient than the fixed hedge ratios in terms of minimizing the risk.

2 - The Hidden Risk of Interest Rate in Carry Trade Return
Jingwen Shi , Qi Wu

This paper studies the role played by interest rates in understanding the forward premium puzzle. Deviating from existing understanding, we find that interest rate risks actually contribute a non-negligible portion of carry premium if looked at through option data. What is more revealing is that, moving up the ladder to higher order moments, especially skewness and kurtosis, interest rate risks contribute more, if not dominant, than exchange rate risk does. Our study is based on a new model that we propose for international asset pricing, where non-Gaussian distributions are essential when specifying dynamics of domestic interest rates and associated exchange rate. The volatility smile phenomenon can thus be captured consistently across interest rate swaptions and currency options. This enables us to retrieve complete distributional information from three option markets simultaneously within one model. Therefore, a risk-attribution study can be carried out structurally across exchange rate and interest rates, as well as quantitatively across different orders of moments.

3 - Exchange rate and trade relationships between Taiwan and three regional economic blocs: A dynamic approach
Mei-Se Chien

The main point of our empirical analysis is to discuss dynamic linkages between the exchange rate and trade elasticity, applied the bilateral data between Taiwan and three trading partners, NAFTA, Euro Area, and ASEAN, from 1998Q1 to 2013Q4. Our main findings are as follows: First, the results of the Gregory and Hansen(1996) test show that the main structural break occurred in the long-run cointegration around three periods, from 2000 to 2001, from 2007 to 2009, and 2010 to 2011, and they look to match clearly with 2000 internet bubble, 2008 global financial crisis and 2010 Euro crisis, respectively. Second, the results of recursive trace statistics show that export, GDP and real exchange rate had one cointegrating vector before 2010 for all of three cases. After 2008 global financial crisis and 2010 Euro Crisis, the number of cointegrating vector is increasing for ASEAN but is decreasing for Euro area after 2010, which shows Taiwan has a more close economic coordination with ASEAN with but a less close economic coordination with Euro area after 2010. There are similar changes of the importing relationship between Taiwan and these two

regional economic blocs. Finally, according to the recursive results of the real exchange rate elasticities of export and import, the depreciating policy to improve the trade balance can just work for the case of bilateral trade relationship between Taiwan and ASEAN.

■ WA-53

Wednesday, 9:00-10:30 - Graham Hills GH614, Level 6

Dynamical Models in Sustainable Development I

Stream: Dynamical Models in Sustainable Development
Invited session
Chair: *Pierre Kunsch*

1 - SunHydrO: Pumped-storage for an improved renewable energy integration. Impact of market price forecast

Ariel Waserhole, Francis Sourd, Pierre Carpentier, Jean-Philippe Chancelier, Michel De Lara

The ever-growing share of renewable energy of the electricity mix represents a new challenge. To cope with the intermittency of renewable production, the SunHydrO project proposes to aggregate different renewable energy sources together with a storage unit in order to sell the global production on the market. The storage enables to increase the value of renewable energy by delaying the sell instant after the production. Moreover, it offers the opportunity to contribute to the system services such as the secondary load-frequency control.

We develop several stochastic optimization models to tackle two problems: first, the design of a storage unit dedicated to renewable energy management; next, the construction of a decision support tool for the daily operations.

In this talk we present an overview of our stochastic models. We study the impact of the market price forecast. We discuss some practical results based on back testing simulations.

2 - Green bubbles and renewable energies

Pierre Kunsch

The risk of creating financial bubbles when providing too generous incentives to renewable energy sources is analysed in this paper by means of SD modelling. The example of the photovoltaic bubble which did explode in Belgium in 2012 is analysed and lessons are drawn for future avoidance.

3 - DO SMART GRIDS BOOST INVESTMENT IN PHOTO-VOLTAICS? The Prosumer Investment Decision

Chiara D'Alpaos, Marina Bertolini, Michele Moretto

In Italy and other EU Member States the last decade was characterized by a large development of distributed generation power plants. Private investments were heavily boosted by monetary incentives, such as feed-in tariffs, especially in the photovoltaic sector. These incentives, on the one hand, allowed for developing photovoltaic technology faster and guaranteed payoffs for huge initial investments, but on the other hand they determined new critical issues for the design and management of the overall energy system and the electric grid especially in the presence of discontinuous sources. Contingent problems that affect local grids (e.g. inefficiency, congestion rents, power outages, etc.) may be solved by the implementation of a "smarter' electric grid. Smart grids represent the evolution of electrical grids and their implementation is challenging the electric market organization and management. The main feature of smart grids is the great increase in production and consumption flexibility. Smart grids give de facto producers and consumers, the opportunity to be active in the market and strategically decide their optimal production/consumption scheme. The paper provides a stochastic theoretical framework to model the prosumer's decision to invest in a photovoltaic power plant, assuming it is integrated in a smart grid. To capture the value of managerial flexibility, a real option approach is implemented and a stochastic dynamic programming problem is solved.

4 - Economic growth, EROI and transition towards renewable energy : a modeling analysis combining system dynamics and optimization

Frederic Lantz

Due to their initial lack of emphasis on energy and natural resources, the economic post-classical growth models suffered the same critic regarding the limits to economic growth imposed by finite Earth resources. Thus, various optimal control models that incorporate energy or natural resources have been developed during the last decades. However, in all these models the importance of the energy return-on-energy-investment (EROI) has never been raised. The EROI is the ratio of the quantity of energy delivered by a given process to the quantity of energy consumed in this same process. Hence, the EROI is a measure of the accessibility of a resource, meaning that the higher the EROI the greater the amount of net energy delivered to society in order to support growth. We build an endogenous growth model subject to the physical limits of the real world (i.e. taking into account the physical constraints of the energy system). The model aims to simulate the transition from a large share of fossil fuels in the energy supply to more renewable energy in this supply combining an optimization model of the economic activity and a dynamical system model of EROI. From an operational perspective, the model is written with both Gams and Vensim (with some routines to transfer the information between the two languages). A first application to Europe is developed.

■ WA-54

Wednesday, 9:00-10:30 - Graham Hills GH617, Level 6

Risk Analysis and Investment Decisions

Stream: Decision Making Modeling and Risk Assessment in the Financial Sector
Invited session
Chair: *Suleyman Ozekici*

1 - Downside Risk and Portfolio Optimization under Loss Averse Preferences

Cristinca Fulga

In this paper, we consider the portfolio problem in the Mean-Risk framework and complement this approach with the consideration of investor's loss aversion. We propose a risk measure calculated only with the downside part of the portfolio return distribution which, we argue, capture better the practical behavior of the loss-averse investor. We establish the properties of the proposed risk measure, study the link with stochastic dominance criteria, point out the relations with Conditional Value at Risk and Lower Partial Moment of first order, and give the explicit formula for the case of scenario-based portfolio optimization. Moreover, in the proposed Mean-Risk model the investor's loss aversion is also captured in the first objective function where the usual expected return is replaced with an expected return - based function that presents the general characteristics of loss aversion. We analyze the efficient portfolios provided by the proposed model and compare them from different viewpoints with the classical Mean-Risk models: Mean-Variance, Mean-Conditional Value at Risk and Mean-Lower Partial Moment of first order. The comparisons between the models were performed using real data. In each case, we describe and interpret the results and emphasize the role and influence of the values of the loss aversion parameters on the optimal solutions.

2 - Investment Strategies, Reversibility and Asymmetric Information.

Xue Cui, Takashi Shibata

This paper investigates the effects of reversibility on a firm's investment timing and quantity strategy under asymmetric information. In particular, we extend the manager-shareholder conflict problem in a real options model by incorporating an abandonment option. We show that higher reversibility induces earlier investment under both full(symmetric) and asymmetric information, but increases the quantity only under asymmetric information. In addition, higher reversibility strengthens the distortion in timing strategy caused by the private information. The delay in investment timing becomes more significant. Finally, we obtain that the private information enhances the sensitivity of quantity strategy on reversibility, but reduces the sensitivity of timing strategy on reversibility.

3 - Portfolio Selection in Prospect Models
Suleyman Ozekici, Abdullah Taskincan

We consider the portfolio selection problem in a market that contains one risky and one risk-free asset using prospect theory. The models discussed involve value functions that are piecewise linear and piecewise exponential. Using different return distributions, each value function is investigated in some details. We derive the solution of the portfolio optimization problem and obtain some interesting properties of optimal prospect portfolios. We present numerical examples to illustrate the irregular shapes of the objective functions and compare optimal solutions for piecewise exponential and exponential value functions.

■ WA-55

Wednesday, 9:00-10:30 - Graham Hills GH626, Level 6

Multicriteria Performance of Funds and Banks

Stream: Operational Research and Quantitative Models in Banking
Invited session
Chair: *Mila Bravo*
Chair: *David Pla-Santamaria*

1 - A multicriteria approach to establishing interest rates for Spanish credit applicants
Javier Reig, Sonia Zendehzaban

A Weighted Goal Programming is proposed to help bank managers score credit applications, especially concerning interest rates. Criteria are based, among others, on: (a) financial ratios; (b) cash flow analysis; (c) bankruptcy predictive models; (d) global rating agencies; (e) market ratios. In order to weight the criteria, bank managers' judgments are taken into account. A case study on firms quoted on the Spanish stock market is developed. Potential extensions include: (a) considering credit characteristics other than interest rates, e.g., the grace period; and (b) fixing prices by companies from quality in competitive markets with product differentiation, e.g., in the building sector.

2 - A 2014 Ranking of Spanish Banks based on European Banking Authority data by using a multicriteria approach.
Mila Bravo, Antonio Benito, Germán Benito-Sarriá

The results of the 2014 EU-wide stress test of 123 banks have been recently published by the European Banking Authority (EBA). This test seeks to assess the resilience of EU banks to adverse economic developments. From a universe of 123 banks, we here focus on the 15 Spanish ones. Our purpose is to rank them according to the EBA criteria by applying the Principle of Moderate Pessimism (Ballestero, 2002). This principle relies on consistent weights and assumes pessimism but not extreme pessimism. Potential users of the paper are government officials, private analysts and managers.

3 - Measuring portfolio risk by a linear proxy for the variance: An empirical research
David Pla-Santamaria, Paz Mendez-rodriguez, Blanca Pérez-Gladish

Portfolio selection relies on quadratic variance as a classical measure of risk. To construct linear models, some linear proxies for the variance are used, but they are not easily accepted in financial analysis due to doubtful accuracy. To find a sound proxy, we undertake an empirical research. From the Footsie blue chips we randomly simulate 1025 portfolios of different characteristics. A regression analysis provides an accurate linear proxy justified by a highly significant goodness of fit.

4 - A multicriteria approach to evaluating project finance in renewable energy projects
Ana Garcia-Bernabeu, Fernando Mayor Vitoria, Francisco Mas-Verdú

We propose a Multiple Criteria Decision Making (MCDM) approach to renewable energy project finance selection to help bank managers decide which are the best projects to be financed using project finance. Recent awareness of environmental issues and the rising use of project finance in this type of projects reinforced the need for research into renewable energy project finance. Project Finance selection can be viewed as an MCDM problem, which requires the consideration of a wide set of criteria. The proposed method allows to easily rank alternatives from several criteria relevant to the bank managers. As an application, a case study applied to renewable energy projects is developed in detail.

■ WA-60

Wednesday, 9:00-10:30 - Graham Hills GH813, Level 8

Evacuation Planning

Stream: Disaster Risk Management
Invited session
Chair: *Marc Goerigk*

1 - Network Design to Anticipate Selfish Routing in the Case of Evacuation
Kerstin Seekircher

When a disaster occurs the population of the endangered zone must be evacuated as fast as possible. In this case, a large number of vehicles move through a street network to reach safe areas. In such a situation it might be impossible to communicate the routes to the evacuees they have to choose to optimize the traffic flow, moreover it is difficult to ensure that the evacuees take the communicated routes. With our approach we optimize the traffic routing without determining optimal routes for every evacuee. In the developed method, the street network for a given traffic flow is optimized. With the blockage of street segments we reach an improvement of traffic distribution what leads to a better traffic flow and results in a faster evacuation. To integrate human behaviour every evacuee is modelled as an independent acting agent that chooses a route dependent on her preferences. So the individual behaviour of the evacuees and also the structure of the street network are integrated in the solution. In a computational study we compare our solution with the results from the unmodified network and with a solution where the optimal routes for every evacuee are given. The results of the computational study indicate that our approach reduces the negative influence of selfish routing on the evacuation.

2 - Shelter location and evacuation routes in emergency logistics: an application to a large volcanic area
Annunziata Esposito Amideo, Antonio Sforza, Claudio Sterle

Natural phenomena have always affected people's way of living. Many are the problems which arise in this context and have to be tackled with effective methodologies. In particular, with reference to natural phenomena such as earthquakes and bradyseism, one of the main problems to deal with is to decide in advance number and position of the shelters, as well as the evacuation routes to exploit to reach them. In the current literature, shelter location decisions have been tackled with variants of the classical facility location problems, e.g., p-median and simple plant facility location problems. These variants have taken into account additional constraints, e.g., minimum and/or maximum capacity for each shelter, as well as specific objective functions, e.g., total distance for evacuating all people, or total risk of located shelters not being operable, etc.. In this work, we propose an application of some models proposed in literature for the shelter location problem. Moreover, we provide in the solution also the evaluation of the evacuation routes' capacity and the time needed to really complete the evacuation process. The real case is related to the area named Phlegraean Fields, a large volcanic area situated at the west of Naples, Italy, around the city of Pozzuoli, which have presented bradyseismic phenomena for a long time, making it a perfect example of area characterized by continuous alert state, requiring the development of emergency logistics operations.

3 - A qualitative formula for evacuation times, based on a case study of a nuclear power plant evacuation
Jan Peter Ohst

Despite high security standards, the effect of an incident in a nuclear power plant can be devastating, not only for the facility itself but for the surrounding area as well. Hence, it is vital to evaluate the evacuation situation in the vicinity of the power plant in case of an emergency. We model the 20 km critical zone around a nuclear power plant as a dynamic network model and use a quickest flow computation to determine lower bounds on the time required to evacuate this zone. Our goal is to examine, how different model parameters, such as the number of cars in the sources, their speed, and their departure times affect the evacuation time. Here especially the influence of time-dependent departure times, which are usually not considered in quickest flow models, results in an interesting behavior. In a case study we compute evacuation times for a large number of scenario parameters. From the results we derive a qualitative formula for the evacuation time, as a function of the model parameters. This can be used to predict lower bounds on the evacuation time for parameter regions that were not considered by the case study, without having to solve additional flow problems.

4 - Flood Evacuation Planning Using a New Approach to Robustness

Marc Goerigk, Horst W. Hamacher, Anika Kinscherff

We consider the problem of evacuating a region due to an inland river flooding, such as in the Elbe basin in 2002 and 2013. As weather forecasts are typically affected by uncertainty, we follow a robust optimization approach to calculate route choices.

The basic idea of this robust approach is the following: Instead of finding a solution which performs best in the worst-case scenario, we ask for a solution that is among the K-best solutions for all scenarios, for a value of K that is as small as possible.

We discuss first theoretical results for this approach and demonstrate its applicability to realistic flood scenarios. Being part of a software tool for real-world problems, we also present a use-case framework and some first visualizations of results.

■ WA-61

Wednesday, 9:00-10:30 - Graham Hills GH816, Level 8

Routing - Industrial Applications

Stream: Routing II - Emerging Applications
Invited session
Chair: *Gunes Erdogan*

1 - Simulating and scheduling truck and trailer operations in a dynamic, heterogeneous and constrained environment.

Olivier Regnier-Coudert, Charles Neau, John McCall, Steven Anderson

Vehicle allocation plays a big role in the health of haulage companies but is also often a challenging task due to the constraints involved and the dynamic nature of the jobs. Recent collaboration with ARR Craib Ltd, a major Scottish road transportation company has led to the formalisation of a new variant of Vehicle Routing Problem (VRP) which involves a heterogeneous fleet of vehicles, the potential use of trailers and a heterogeneous set of jobs, each with distinct constraints. Using both constructive and evolutionary approaches, several solvers were derived, generating vehicle allocation recommendations in real-time.

Assessing the performance of the solvers is essential prior to integrating it to the operations and thus, a simulation bench was developed. Using operational data recorded at ARR Craib, the framework is able to account for the dynamism of the jobs and simulate operations based on the solver's recommendations. In this work, we present the strategy behind the simulation, including features such as travel time estimation methods, policy modelling or resampling techniques.

Although originally designed for validation purposes, the simulation framework can also benefit fleet planning, policy management or be used for staff training. By exploring different scenarios on real data, we demonstrate how key management decisions such as fleet reduction, changes in driver qualification policies or changes in trailer usage restriction would impact the operations.

2 - A Multi-compartment Vehicle Routing Problem for Incompatible Products

Bahar Turan, Levent Kandiller, Deniz Türsel Eliiyi

Vehicle Routing Problem (VRP) tries to satisfy customer demands from one or more depots by a given set of vehicles within a given time period. Various objectives can be considered including minimizing the total distance, time or vehicle usage, minimizing the maximum tour length or maximum time, load balancing or optimizing certain humanitarian metrics. A vast amount of VRP literature exists covering several variants of the problem. In this study, we consider a real life instance of a multi-compartment VRP with incompatible products in a livestock feed distribution system, where each livestock farm demands one type of feed from a single depot. The objective is to minimize the total cost of distribution including the traveling costs. The problem situation is analyzed and a general mathematical model is formulated. A computational experiment is designed for testing the effect of uncontrollable parameters on the performance of the developed model. Our results indicate that the developed methodology is applicable to the real life logistics problems of food, fuel and other chemical distribution problems.

3 - An Open Source Spreadsheet Solver for Vehicle Routing Problems

Gunes Erdogan

The standard quantitative analysis software for small to medium scale businesses has been established as, arguably, Microsoft Excel. On the other hand, most academics develop optimization algorithms in C++ and JAVA. Distance and driving time data have to be retrieved from a Geographical Information Systems database. Assembling the data sources, solution algorithms, and visual representation of the results of a Vehicle Routing Problem (VRP) into a single platform is a problem on its own. In this talk, we present an open source VBA code embedded into an Excel file, which can retrieve data from public GIS, solve the VRP instances, and visualize the result. Familiarity of the business world with Excel as well as the public availability and visibility of the code facilitate the widespread use of the solver, and hold the promise for enabling greener logistics practice.

4 - Optimization of workers transport in a company using the algorithm of Clarke & Wright

Wilmer Atoche

This research shows the evaluation of alternative routes you want to get a company providing transportation services to their employees, which is the movement of a point in common for the district to the plant by the algorithm savings Clarke & Wright. The current situation shows that the transport leaves the plant, follows a route that picks up workers established bus stops and moves to the company; however, it is proposed to establish a central whereabouts on a street or strip easily accessible to all workers in a district. The main objective is to reduce the costs of this service and offer workers: comfort, safety and satisfaction. The results show significant savings in time and money for the company if the new vehicle routes are established.

■ WA-62

Wednesday, 9:00-10:30 - Livingstone LT203, Level 2

Operations Research 9

Stream: Operations Research, other
Contributed session
Chair: *Frédéric Gardi*

1 - Feasible Optimization

Vincent Cliville, Salvatore Greco, Salvatore Corrente, Bastien Rizzon

We consider a decision problem related to the future configuration selection in a complex system (for example an enterprise) to improve its performances. We formulate the problem considering a set of criteria representing the axis on which the performances of the considered system are evaluated, and a set of alternative configurations of the system, possibly infinite. It means that a priori every configuring of the system can be considered. We consider that overall preference or indifference relation can be defined for a given pair of alternatives, each alternative being represented by a value function. We consider also a feasibility function such as it is possible to pass from a given alternative to another one if and only if the feasibility of the first alternative is higher than the second one. Also the feasibility function is non decreasing in all its arguments. In this context, the optimal configuration of the

considered system, having current configuration could be obtained by the solving the following optimization problem: maximizing the utility value under the constraint of feasibility. We assume that both the value function and the feasibility function have an additive form. Moreover the both marginal utility and feasibility according each criterion are non decreasing. We propose to assess the value and feasibility functions in an indirect way by ordinal regression through the UTA method, which is a rather well known procedure for obtaining a value function.

2 - Initial Allocation of Emission Certificates Using Data Envelopment Analysis
Mikulas Luptacik

In the emission trading two approaches to determine the amount of certificates allocated to each plant can be used. One is called "grandfathering" and the other is named "update". The basic difference is that the grandfathering mechanism uses historic emission information of the different plants to calculate the allocation, whereas in the update method current and future data form the basis for the certificate distribution. In the paper we propose an alternative initial allocation of the emission certificates based on the eco-efficiency of the firms. The eco-efficiency is defined such that the goods and services (or desirable outputs) should be produced with less energy and resources (or inputs) and with less waste and emissions (or undesirable outputs). Because of the different units in which the desirable and undesirable outputs are measured, data envelopment analysis (DEA) for eco-efficiency measurement is used. DEA models — as developed by Korhonen - Luptacik (2004) — taking into account the inputs, the pollutants and the desirable outputs simultaneously indicate the potential reduction of the emissions and thereupon provide a decision support for an incentive based allocation mechanism. The amount of free allocated certificates to the plants is based on their eco-efficiency scores.

■ WA-66
Wednesday, 9:00-10:30 - Livingstone LT209, Level 2

Spanning trees

Stream: Optimization
Invited session
Chair: *Gómez-Rúa María*

1 - Optimal layout of a parking lot and the maximum leaf spanning tree problem
Michael Stiglmayr

We consider the problem to determine an optimal layout for a parking lot such that a maximal number of cars can be placed. The parking lot has rectangular shape, a given size and one exit in a corner. We model this problem by dividing the parking lot into m times n unit squares, which represent either individual parking spaces or parts of the streets connecting them to the exit. We present two different integer programming formulations for this combinatorial optimization problem. The difference between these two models is the way in which the 'connection-to-the-exit' constraint is implemented. One can show that the optimal structure for the streets is a tree whose leafs represent the individual parking spaces. We present a heuristic to efficiently generate a very good feasible solution, and a bounding scheme for the maximal number of parking lots in a given region.

2 - Improving sensitivity analysis with multiple cost changes of the Minimum Spanning Tree Problem using upper tolerances
Marcel Turkensteen, *Kim Allan Andersen*

The Minimum Spanning Tree Problem (MSTP) is the problem of finding a set of edges in a network, such that the sum of the costs of the edges are minimized and such that all vertices in the network are connected with each other through paths consisting of the selected edges. The problem has many applications, for example, in network design. We address the issue of the stability of the optimal solution with respect to simultaneous changes in multiple edge weights. If these simultaneous changes are not proportional to a known change direction, we can determine whether the current solution remains optimal using the so-called 100% rule.

We introduce a new approach based on upper tolerances of the edges in the optimal MSTP, where an upper tolerance is, roughly spoken, the

maximum increase in an edge value before it leaves an optimal solution. We show that an edge remains in an optimal MSTP solution as long as the cost increase of that edge is lower than its upper tolerance value, also if the weights of other edges are changed, as long as the weight of none of them decreases. We use this finding for the so-called upper tolerance-based rule that determines whether the optimal solution remains the same and if not, which edges remain in an optimal solution. We find that the upper tolerance-based rule is much better able than the 100% rule to predict whether the solution remains the same for different types of cost changes.

3 - A monotonic and merge-proof rule in minimum cost spanning tree situations
Gómez-Rúa María, *Juan Vidal-Puga*
We present a new model for cost sharing in minimum cost spanning tree problems, so that the planner can identify the agents that merge. Under this new framework, and as opposed to the traditional model, there exist rules that satisfy merge-proofness. Besides, by strengthening this property and adding some other properties, such as population monotonicity and solidarity, we characterize a unique rule that coincides with the weighted Shapley value of an associated cost game.

■ WA-67
Wednesday, 9:00-10:30 - Livingstone LT210, Level 2

Vehicle Routing and Combinatorial Optimization

Stream: Combinatorial Optimization
Invited session
Chair: *Kamil Erkan Kabak*
Chair: *Victor Juarez-Luna*

1 - Periodic Vehicle Routing Problem with Two Types of Visits
Okan Altınkök, *Ahmet Camcı*, *Ozgur Ozpeynirci*
Periodic vehicle routing problem (PVRP) is a variant of the classical vehicle routing problem. PVRP is based on visiting customers once or more during a planning horizon with multiple days. The problem decides the customers to be visited and the routes for each day. In general, the goal is to minimize the total length of the routes. Organizing the visit days properly provides an important advantage to decrease delivery costs and the number of vehicles. Our problem involves two types of visits that must be on consecutive days in PVRP setting. The first type visit to the customer is for collecting demand information and increasing the visibility of the products at the store, whereas the second customer visit is for delivering the goods. The first type visits take place with small and fast vehicles under time capacity constraints. On the other hand, the second type visits require relatively large scale, slow and physical capacitated vehicles. Hence using the same routes for the consecutive days might not be feasible. In this study, we firstly show that this problem is NP-Hard. We propose a special lower bound algorithm for the problem and a heuristic algorithm based on Variable Neighborhood Search (VNS). We conduct computational tests on the modified versions of the widely used test instances.

2 - BRKGA for the Capacitated Open Vehicle Routing Problem
Victor Juarez-Luna, *Efrain Ruiz*
This talk focuses on the capacitated open vehicle routing problem (OVRP). Given a central depot a set of vehicles with a given capacity and a set of clients with specified demands that should be satisfied, the goal is to determinate a set routes that minimize the cost for delivering the goods to the clients considering that the vehicles end their routes after servicing the last client.

The OVRP is to determinate the number of vehicles to be used and establish their routes to serve the clients at minimum cost without forcing vehicles to return to the depot. A biased random-key genetic algorithm (BRKGA) is a metaheuristic in which populations of random vectors evolve to find good quality solutions for the problem. The BRKGA is used in combinatorial optimization problems, for which solutions are encoded into random vectors. This paper explores a solution encoding and proposes a BRKGA heuristic for the OVRP problem. Computational experiments using sets of benchmark instances are presented showing that the proposed algorithm is able to find good quality solutions using a modest computational effort.

3 - A Capacitated Vehicle Scheduling Problem with Time Windows: A Case Study from the Beverage Sector
Kamil Erkan Kabak, Arslan Ornek

Supply networks and distribution activities have broad-ranging implementations in different sectors. Analysis of them reveals that vehicle scheduling problems could be very complex and difficult to solve. Thus, they cause significant time losses and increases distribution costs. In this study, we consider a special type of Capacitated Vehicle Routing Problem (CVRP). The problem is to determine the optimal number of delivery clusters. This is achieved balancing and reducing total trip times among and within clusters. A binary integer mathematical programming model is developed for the problem and it is solved by a general heuristic method. Further, the results are also tested by a simulation model.

■ WA-78

Wednesday, 9:00-10:30 - Architecture AR201, Level 2

Societal Complexity and Economy

Stream: Methodology of Societal Complexity
Invited session
Chair: *Dorien DeTombe*
Chair: *Antoinette Muntjewerff*

1 - Trap of Economics the World Has Fallen in
Eizo Kinoshita

This paper is a survey of Kinoshita's Macro-Economic theory and new Macro-Economic paradigm. Throughout my study,I proclaims there are two economic phases: one is expressed primal problem, and another is expressed its dual problem. And I states that the two economic phases have duality relations. My theory reaches analysis of global trade, bubble economy and its crash. My main tools for the analysis are linear programing on operations research.

2 - Dependency on Computer Systems a Threat for Privacy and Safety
Dorien DeTombe

The last 25 years the world became increasingly dependent on computers. Electronic data exchange is imbedded in the world beyond excluding. Computers are a blessing and a threat. For many items the computer is very handy, but can also be a threat. People can easily be followed though their telephones, iPad and computers and data are collected by states. Big brother is watching you is no longer Science Fiction. Social media enlarges the privacy vulnerability of men, women and children beyond control. Next to this there is a huge dependency on computer systems for water and air supplies, hospitals, banking and military missions. The worldwide banking system is dependent on computer systems and we are dependent on these systems by manipulating the stocks by flash programs. These computer systems are easy targets for corruption, fraud and terrorism. Huge disaster scenarios are thinkable and possible. We will address some issues of the vulnerability to computers in relation to safety and privacy by using the Compram methodology to analyze, define, and predict some of the (future) computer threats. In 2006 the Compram methodology, developed by DeTombe, is advised by the OECD to use as the methodology to handle global safety.

DeTombe, Dorien (2015) Handling Societal Complexity. A Study of the Theory and the Methodology of Societal Complexity and the COMPRAM Methodology. Heidelberg: Springer Verlag. ISBN: 978-3-662-43916-6 (Print) 978-3-662-43917-3 (Online).

■ WA-79

Wednesday, 9:00-10:30 - Architecture AR310, Level 3

Performance Analysis in Sports

Stream: OR in Sports
Invited session
Chair: *Raymond Stefani*

1 - On the search of fair score systems to evaluate some sport competitions
Montserrat Pons, Josep Freixas, Nadezhda Smirnova

We study scoring systems and combinations of them with the purpose to evaluate athletes' performances for artistic sports such as diving, synchronized swimming, figure skating, rhythmic gymnastics by taking into account the entire judge's scores but also the variability of these scores. The new method we propose based on scoring systems only depends on the number of judges and on the ordering of their evaluations, but not on other comparisons among them. The proposal has several interesting properties: (1) it is simple and easy to be understood for the audience, (2) it is representative because it does not discard any judge's evaluation, (3) it is hardly manipulable, (4) it is well-defined for any committee with an arbitrary number of judges, and (5) the method proposed is also useful to evaluate the post judges' reliability.

2 - Analyzing Batsmen Performance in Cricket: Invoking Markowitz and Sharpe
Uday Damodaran

Individual player's contribution to the team performance is more easily measurable and attributable in the game of cricket than in other team games. However, surprisingly little work has been done in this area. This paper draws upon the pioneering work done by financial economists Markowitz and Sharpe in the area of security analysis and portfolio management to develop a framework for evaluating a batsman's utility in terms of contribution to the team performance. In the current paper, for the fifty overs format of the game, analogous to the Markowitz-Sharpe framework, a methodology is proposed to evaluate batsmen's utility on three attributes: the average of runs scored, the standard deviation of runs scored, and the co-movement between the batsman's performance and the team's overall batting performance. To arrive at a utility value for each batsman an analysis is attempted assuming that a batsman who scores more with lesser variability and who performs well/ poorly when the team as a whole under/ over-performs would be considered more valuable than a batsman who scores lesser with greater variability and who performs well/poorly when the team as a whole over/ under-performs. The analysis is demonstrated using the data for the Indian One Day International (ODI) cricket team.

3 - A powerful test for the relative age effect
Jonas Andersson, Jarle Møen

We revisit data sets used by Delorme et al.(2010) and others to investigate whether those born early in the year are overrepresented among elite athletes. Our main contribution is an easily implemented technique that increases the probability of detecting this so called relative age effect significantly. The technique is presented and analysed in detail. Asymptotic results are given and small sample results are given by means of a Monte Carlo study. Finally the method is applied to the data.

4 - Understanding the Female/Male Velocity Ratio of Olympic Champions in Running, Swimming and Rowing Using OR Methodology
Raymond Stefani

Following OR methods, we observe past performances, create a model, populate the model with measurements, compare the model with actual results for validation and draw conclusions. There appear to be few observed physical difference between past and present Olympic male and female champions in running, swimming and rowing. The female champions improved faster than their male counterparts until the late 1970s. After that time, both genders improved at about the same rate. A model of athletic performance is created based on power output which is then populated with parameters calculated from 13 studies involving 2286 elite athletes. Assuming that men and women are currently equally trained, equally efficient and use similar equipment, the velocity ratio for female/male Olympic champions should be close to estimates based only on physiology for each sport. In fact, that was the case. Elite female athletes were about 90% as lean as their male counterparts, and indeed female Olympic champions in running swimming and rowing were about 90% as fast as the male champions from 1980-2012. Power-to-weight relationships are given to aid in training.

■ WA-80

Wednesday, 9:00-10:30 - Architecture AR311, Level 3

Mathematical Economics: Real World Applications

Stream: Mathematical Economics
Invited session
Chair: *Alan Pearman*

1 - Consistent Collective Decisions Under Majorities Based on Differences
Mostapha Diss, Patrizia Pérez-Asurmendi

The main criticism to the aggregation of individual preferences under majority rules refers to the possibility of reaching inconsistent collective decisions from the election process. In these cases, the collective preference includes cycles and even could prevent the election of any alternative as the collective choice. The likelihood of consistent outcomes under two classes of majority rules constitutes the aim of this paper. Specifically, we focus on majority rules that require certain consensus in individual preferences to declare an alternative as the winner. In the case of majorities based on difference of votes, such requirement asks to the winner alternative to obtain a difference in votes with respect to the loser alternative taken into account that individuals are endowed with weak preference orderings. Same requirement is asked to the restriction of these rules to individual linear preferences, whereas in the case of majorities based on difference in support, the requirement has to do with the difference in the sum of the intensities for the alternatives in contest.

2 - Equilibria in a Network Game with Production and Knowledge Externalities
Vladimir Matveenko, Alexei Korolev

We continue the line of recent research of Nash equilibria in networks in presence of positive externalities; we focus on investment externalities. We consider a network, in each node of which, i=1,2,...,n there is an agent, whose preferences in time periods 1, 2 are described by a utility function. In period 1 each agent receives endowment e to use for immediate consumption and investment into knowledge. For agent i, the externality is the sum of her neighbors' investments; the environment is the externality plus her own investment. The production function depends on the own investment and the environment; when making decision, the agent takes the environment as exogenously given. We study a game, in which strategies are investments, and payoffs are utilities. If a profile defines a consistent set of environments and optimal solutions, it is referred as Nash equilibrium with externalities. We characterize the ways of behavior of an agent: passive (no investment), active, and hyperactive (the whole e is invested) in dependence on the size of received externality. We prove the uniqueness of the inner equilibrium, when it exists, and study its dependence on the network structure. We introduce a notion of the type of node and propose an algorithm for identification the types. We show that networks of different sizes but similar structure of types of nodes, possess similar inner equilibria. We study changes of equilibrium under various transformations of the network.

3 - An Experimental Exploration of Behaviour Patterns in a Mixed Strategy Two-Person Game
Alan Pearman, Simon McNair, Ken-Ichi Shimomura, Barbara Summers

The classic rock — paper — scissors (R-P-S) game continues to be a commonly used example in introductory discussions of game theory. It is widely understood internationally, familiar to many people since childhood and serves as a convenient basis from which to start to explore game theory concepts such as payoffs, choice of playing strategy, Nash equilibria, etc. In recent years, a range of experimental studies has begun to develop investigating the behaviour of individuals playing R-P-S. The initial focus has been descriptive — what people actually do — as opposed to prescriptive — what they should do in order to be seen to be acting rationally. However, the number of such studies is still quite limited and, for the most part, they restrict themselves to the classic R-P-S game alone and to issues such as imitation of opponents' strategies and cycling of strategies.

In this paper, we report a broader set of results concerning a game one level more complex than classic R-P-S and thus less open to ready identification of an optimal strategy. We focus on experimental evidence of how human subjects play repetitions of the game and explore how effective their chosen strategies are, whether and how they evolve over time and, in our view importantly, whether observed patterns of behaviour correlate with any of a series of indicators of individual difference such as need for cognition, locus of control, maximising/satisficing and preference for affect.

4 - Firm Dynamics in a Radner Model
Stanislav Radionov, Igor Pospelov

Radner model is one of the cornerstones of the financial mathematics literature. In this model, firm faces a random flow of profit and chooses an optimal dividend policy in order to maximize a discounted sum of dividends before bankrupcy. Optimal control problem was solved in the original article by Radner, but the full description of the firm dynamics is not yet presented in the literature. To partially fill this gap, we derive and solve the partial differential equation describing firm's dynamics, calculate the expected flow of dividends and distribution of bankrupcy time and analyze their dependence on the parameters of the model.

5 - Effective Numerical Methods for Optimal Tariff Policy of Railway Cargo Transportation
Sergey Gorodetskiy, Marina Kaznacheeva

Recently A. Shananin et al. (arXiv:1501.02205) proposed a primal-dual convex optimization problem for searching equilibrium in the model of railway cargo transportation. We proposed a new evolutionary interpretation of this equilibrium (due to W. Sandholm, 2010). Moreover, we compare this model with two different types of traffic flow distribution models. The first model is called Beckmann's model and the second one is called the stable dynamical model (Nesterov-dePalma, 2003). We show that Shananin's model is in a sense a combination of these two models. So the natural question is: if we know the optimal numerical methods for searching equilibriums in these models, how are we to find an optimal method for combination of these models? We will answer this question. In other words, we propose a new effective numerical (randomized) method for solving primal-dual convex optimization problem proposed by A. Shananin et al. This method is based on randomized version of Nesterov's dual averaging method (Math. Prog., 2009). We solve the dual problem. In this problem the functional is represented as a sum of several functions. Instead of calculating the full sub-gradient, at each iteration we choose at random one of the items of the sum and restrict ourselves to calculating this item's sub-gradient.

■ WA-82

Wednesday, 9:00-10:30 - Architecture AR401b, Level 4

Scheduling in Healthcare 1

Stream: Scheduling in Healthcare
Invited session
Chair: *Rosita Guido*

1 - Development of Scheduling Models for Operating Rooms in the Public Health System
Matias Iordache, Alejandro Cataldo, Sergio Maturana

The purpose of this paper is to study the use of scheduling models for elective surgery patients and to obtain guidelines that can be derived from the resolution of these models. With the aim of improving the quality of service delivered, we proposed the development of programming models using different methodologies including the formulation of a mixed integer linear model and a dynamic stochastic model and then we solved both of them in order to obtain the optimal allocation of resources involved, taking into account the specific constraints of the system in which it is implemented and also allowing to select patients using an objective and measurable criteria, a topic that often takes a backseat in many investigations. We evaluated the model using various case scenarios with different amounts of people on the waiting lists. The use of these models would be very complex for decision makers who generally do not have the skills required to run the optimization models or to modify them, so the results obtained by the models were analyzed and a set of optimal policies are determined to ease the process of decision making.

2 - Dynamic Scheduling of Outpatient Physiotherapy Treatments Appointments
Ignacio Lazo, Sergio Maturana

Scheduling physiotherapy treatments appointments in a hospital faced with a very high demand is complex. The current system in a Chilean public hospital results in many patients having to wait long times before starting their treatments, with very bad health consequences for the patients. This hospital has three different types of therapy specialists, who are the ones that perform the therapy. Before undergoing the therapy, patients must see the traumatologist, who is the one that indicates the appropriate treatment. After completing the treatment, patients must see the traumatologist again to determine if they are discharged or if they have to undergo more treatment. We propose a scheduling system that addresses two key questions: how much of the traumatologist resources to reserve for diagnose and discharge; and how often should a patient be treated by the therapy specialists. In order to reduce the waiting time (diagnose or discharge), and assure that sessions are evenly spread, we developed a deterministic model that assigns patients to a given therapy specialist and then schedules the treatment sessions. Given the stochastic and dynamic environment we faced, we also developed a Markov Decision Process that tries to provide a scheduling policy that would improve the performance of the actual system by effectively allocating the available resources while taking into account the upcoming demand.

3 - A Rolling Horizon Approach for the Home Health Care Problem
Daniela Lüers, Leena Suhl

Home health care is a growing sector in public health. The difference to other health care institutions is that clients receiving services stay at their own homes. Thus, the home care providers face a complex routing and scheduling task to plan the services for a given time period. Not only the routes of the nurses have to be determined, but working regulations and skill requirements have to be considered. The home health care problem in operations research literature addresses these issues and mostly provides one schedule for subsequent days or weeks. During this period, it is necessary that a schedule can be adjusted, e.g. due to incorporation of new clients or sudden personnel unavailability. We propose an optimization approach with a rolling horizon to cope with these alterations and to revise an existent schedule. In every planning period the former schedule has to be considered in order to avoid drastic changes. Too many or major variations would lead to lower client satisfaction as the clients have to adapt to the new schedule after each alteration. The same holds for the employee satisfaction. Therefore, our heuristic solution approach considers the continuity between different planning periods. We present computational results and an analysis of different continuity measures.

4 - Fairness, Social Welfare and Starvation of Resources in Nurse Rostering
Antonios Glampedakis, Djamila Ouelhadj, Dylan Jones, Simon Martin

Many operations research (OR) problems like scheduling and timetabling, are associated with evaluating the distribution of resources in a set of entities. This set of entities can be defined as a society having some common traits. The evaluation of the distribution is traditionally done with a utilitarian approach, or using some statistical methods. In order to gain a more in depth view of distributions in problem solving we propose new measures and models from the fields of Computer Science, Economics, and Sociology, as well Operational Research. These models focus on 3 concepts: fairness (minimisation of inequalities), social welfare (combination of fairness and efficiency) and poverty (starvation of resources). We also propose a MCDM model, combining utilitarian, fairness and poverty measures. These measures and models are applied to the nurse rostering problem from a central decision maker point of view. Nurses are treated as a society, trying to optimise nurse satisfaction. Nurse satisfaction is investigated independently from the hospital management, forming two conflicting criteria. The results from different measures cannot be evaluated using cardinal measures, so Multiple Criteria methods and Lorenz Curves are used instead.

Operations Research in Medicine

Stream: Health Care Management
Invited session
Chair: *Brian Denton*

1 - Quantifying the trade-off between IMRT treatment plan quality and delivery efficiency
Edwin Romeijn, Eshan Salari

Beam-on-time is an important measure of the delivery efficiency in Intensity-Modulated Radiation Therapy (IMRT). Traditionally, minimizing beam-on-time has been postponed until the Leaf Sequencing stage where the treatment plan quality is already determined and fixed. However, there is a trade-off between the beam-on-time and the treatment plan quality. The aim of this study is to incorporate the beam-on-time into the treatment-plan optimization stage using, which will allow for explicitly quantifying the trade-off. This approach can provide clinicians with valuable information for each patient case so that they can design a clinically-attractive and at the same time efficient treatment plan. We use the special structure of the problem to develop both an exact and an approximate solution approach. Our approximate technique is tested on clinical cancer cases and its performance is compared to general approximation techniques available for convex bi-criteria optimization problems. The experiments validate that our approach can achieve a more accurate representation of the Pareto-efficient frontier with less computational effort.

2 - Matheuristic TSrad for the selection of beams directions and dose distribution in Radiotherapy Planning
Thalita Obal, Dylan Jones, Djamila Ouelhadj, Helenice Florentino, Neida Maria Patias Volpi

Radiotherapy planning involves the problems of how to position the machine (beams directions problem), and how much dose delivery through each beam (dose distribution problem). This research proposes the matheuristic TSrad, a hybrid search method which combines Tabu Search (TS) and the exact method of Interior Point. TS is used to select the beams directions and Interior Point to solve the dose distribution problem. Each TS solution represents a set of the selected beams from a set of possible ones. The objective function value of each TS's solution is determined by Interior Point method, as proposed by Obal et al. (2013). Computational experiments have been conducted to evaluate the performance of TSrad and and its results have been compared to the exact method proposed in Gevert et al. (2013). The case study considered is the prostate cancer, using four instances with different sizes of possible beams to be selected. The experimental results have shown that TSrad has achieved a good quality solution with substantial improvements in computational time.

Gevert V G, Obal T M, Volpi N M P and Wilhelm V E. 2013 Um modelo de otimização integrado para os problemas da escolha de feixes de radiação e do mapa de fluência em radioterapia. SBPO, XLV. Natal/RN. Anais. Sociedade Brasileira de Pesquisa Operacional.

Obal T M, Volpi N P and Miloca S A. 2013 Multiobjective approach in plans for treatment of cancer by radiotherapy. Pesquisa Operacional 33 (2) 269-282.

3 - Biomarker-Based Screening Strategies for Early Detection of Prostate Cancer
Brian Denton, Christine Barnett, Scott Tomlins, John Wei

Prostate cancer is the most common solid tumor that affects American men. Screening typically involves the use of prostate specific antigen (PSA) tests. However, the imperfect nature of PSA tests and the fact that many cancers are likely indolent, means there is the potential for screening to cause harm due to unnecessary biopsies and treatment. Newly discovered biomarkers offer the opportunity to improve screening protocols, but there high cost and imperfect predictive value have raised many questions about whether and when to use them. In this talk I will provide some background on the clinical process for prostate cancer screening and treatment. Next, I will discuss some models for the optimal design of screening strategies, including a partially observable Markov decision process (POMDP) model. Some theoretical properties of the optimal policy will be discussed, and an approximation method suited to solving finite horizon non-stationary POMDPs will be presented. The results of computational experiments will be used to illustrate the use of the model for making screening

protocol design decisions, such as if and when to recommend a patient for biomarker testing, and when to refer patients for biopsy and subsequent treatment. The talk will conclude with a discussion of future research directions.

4 - Quantitative Modeling of Behavior Change for Personalized Weight Loss Interventions
Anil Aswani, Elena Flowers, Yoshimi Fukuoka, Phil Kaminsky, Yonatan Mintz

Seventy percent of American adults are overweight/obese, and related costs are estimated at $147 billion annually. Programs combining exercise and caloric restriction can lead to weight loss, but the challenge is ensuring continued participation in these labor-intensive and often expensive programs. This talk describes two quantitative models of behavior change using individual-level mobile health data from a weight loss intervention. We believe such models can be used to personalize interventions to improve adherence and lower costs. The first model uses support vector machines (SVM's) from machine learning, and prediction is accomplished via standard formulations. The second is a utility maximization model with elements of "irrationality", and we show it can be constructed by solving a sequence of mixed-integer linear programs. We also describe a new mixed-integer formulation for incorporating empirical prior distributions into a Bayesian maximum a posteriori (MAP) framework for making predictions. These models use data collected during the mDPP trial (Mobile Phone Delivered Diabetes Prevention Program Trial), which is a randomized controlled trial (RCT) with 2 groups (mobile app and accelerometer-alone groups). The primary goal of this RCT was to evaluate the feasibility and potential efficacy of a 5-month mobile phone delivered diabetes prevention intervention in changing body mass index (BMI) among overweight/obese adults at risk for developing type 2 diabetes.

Wednesday, 11:00-12:00

■ WB-01

Wednesday, 11:00-12:00 - Barony Great Hall

Plenary Lecture: M. Grazia Speranza

Stream: Plenary, Keynote and Tutorial Sessions
Plenary session
Chair: *Daniele Vigo*

1 - Trends in Transportation and Logistics
M. Grazia Speranza

Operational research has, in the second part of the last century, given a massive contribution to the modeling and solution of complex problems in transportation and logistics, with the consequent implementation of sophisticated methods and development of software that has had a huge impact on the competitiveness of a number of companies. In this talk the major contributions of our discipline will be overviewed.

Technological changes have been dramatic in the last couple of decades. Information and communications technologies (ICT) nowadays enable users to access, store, transmit, and manipulate information. The limitations in data availability and communication possibilities our discipline has experienced in the past have been overcome. At the same time, the ICT, combined the globalization phenomena, have created new opportunities and expectations in companies, institutions and citizens. Opportunities and expectations are often accompanied by new risks. Environments are dynamic and uncertain. At the same time coordination possibilities are enormous. Advanced analytical methods and a systemic approach to problems are even more vital than in the past. Our discipline is faced with new challenges and new opportunities. In this talk some of the most promising research directions in the field of transportation and logistics will be discussed.

Wednesday, 12:30-14:00

■ WC-01

Wednesday, 12:30-14:00 - Barony Great Hall

Tutorial Lecture: Jacek Blazewicz

Stream: Plenary, Keynote and Tutorial Sessions
Tutorial session
Chair: *Patrick De Causmaecker*

1 - OR Models and Algorithms for Bioinformatics
Jacek Blazewicz

In the talk we will present the operational research models and approaches to the solution of the prominent problems in Bioinformatics. A special attention will be paid to the DNA and RNA chain reading problems. First, the DNA sequencing problem will be analyzed. Based on it, the algorithms solving the DNA assembling problem, involving 454 sequencers, will be characterized. An impact of this approach on the graph theory itself will be also presented. Later, the problem of a prediction of tertiary structures of RNA will be described. We will present its complicated nature and a set of computational procedures leading to its solution. The impact of the above problems on solving health issues of the current human population will be also discussed.

■ WC-02

Wednesday, 12:30-14:00 - Barony Bicentenary Hall

EthOR Award - Finalists' Presentations and Award Ceremony

Stream: OR and Ethics
Invited session
Chair: *Erik Kropat*
Chair: *Cristobal Miralles*
Chair: *Gerhard-Wilhelm Weber*

1 - Pricing and Inventory Management for Deteriorating Items taking into account Customer Returns and Time Value of Money
Maryam Ghoreishi

With different parties involved in the supply chain process there is always a question of how to develop problems which incorporate the fair and realistic conditions. So, the innovations in this M.Sc. study can truly be expressed in terms of Responsibility and "OR and Ethics". Pricing and replenishment strategies have traditionally been determined by entirely separate units of marketing and operational planning, respectively. But, today, we could not rely on the traditional models and should coordinate these two planning areas while maximizing the revenue. Moreover, the effect of deterioration, inflation and customer returns is very important in determining the optimal pricing and inventory control policy. Thus, this M.Sc. thesis proposes five main models based on joint optimal pricing and inventory control policy for deteriorating items. The thesis contributions are supported by several peer-reviewed publications in journals included in ISI-JCR.

2 - An Exact Solution to the Joint-Pollution Routing of a Heterogeneous Fleet of Reefers along Two Horizontally-Collaborative Cold Supply Chain Networks
Lamis Amer

The concept of Horizontal Collaboration and pooling of supply chains has been introduced by the European Union in 2001 as one of the innovative green supply chain practices. Although it is reported that horizontally collaborative supply chain practices has both economic and ecological implications, however, only economic concerns have been widely addressed in literature. To contribute to the body of knowledge, this dissertation focuses on the Joint-Vehicle Routing Problem with the consideration of wider objectives that are concerned with sustainable

logistics issues through integrating the environmental problem dimensions represented in minimizing emissions and fuel consumption, in addition to the carriers' joint routing aspects. In this context, this work contributes to the research on green logistics through the proposition of the combinatorial Joint-Pollution Routing optimization problem. This problem is motivated by · Develop a thermodynamics-based methodology to evaluate energy consumption of refrigerated trucks, and extend the Pollution Routing Problem to examine the effect of adding refrigeration energy consumption. · Solve the Joint-Pollution Routing Problem and evaluate the implications of integrating horizontal collaboration decisions while solving the energy-minimizing vehicle routing problem along cold supply chains.

3 - Modeling of Sustainable Development for Municipalities Using the Complex Indicators' structure
Anastasiia Lisogor

One of the current problems of the modern society is to achieve sustainable development as a balance between quality and security of life. The concept of triple bottom line is used for solving this problem on global level for countries and regions. This includes economic activity, social and environmental influence. The achievement of sustainable development in global scale is a long-term project. A city needs less time for changes and could be managed through the direct feedback and indicators dynamic analysis. Lack of attention to the problems of sustainable development of municipalities or the not rational decision making process in this field can lead to a sharp increase in disparities characteristics, total destabilization and uncontrollability of the system. Differences in life quality and economical development lead to additional verification of methods and approaches for sustainable cities in different countries. The main goal is to develop the model for describing the sustainable development for municipalities in purposes of its analysis, simulations and forecasting. This includes: the analysis of modern methods and methodologies in sustainable development modeling, the analysis of key factors of municipalities operations, drawing out the hierarchy model of sustainable development, creating the data base for indicators, calculation of the results in dynamics and their visualization, and presenting city ranks on web portal for supporting the decision-making processes.

■ WC-06

Wednesday, 12:30-14:00 - TIC Lecture Theatre, Level 1

POM IV

Stream: Production and Operations Management
Invited session
Chair: *Guillaume Amand*

1 - The Effect of the Interaction between Learning and Process Change on Ramp-Up Performance: A simulation-based Analysis
Peter Bußwolder

The phase of the production ramp-up is characterized by limited knowledge and poorly understood processes, which cause a low production rate and a low level of quality. As sources for possible improvements, this study incorporates a normative discrete-event simulation model with an agent-based workforce to analyze the effects of workforce learning and process change on ramp-up performance. Two sources of improvement are considered. First, workers learn autonomously through learning by doing. This is represented by the learning curve. They additionally learn through investment in training. Second, through investment in engineering analysis, the effective capacity can be increased. Changes in the production process may lead to a loss of knowledge through depreciation of knowledge, considering that a part of the knowledge acquired through learning by doing is specific to the environment and gets obsolete. These disruptions have a negative impact on future time periods. This is because knowledge increases the gains in effective capacity, derived from process change, but as a part of the cumulative knowledge gets lost, the capability for further process changes gets lowered. The results show that highly skilled workers, reduce the need for training in early periods, but the loss of knowledge, makes training necessary for later periods. If even small changes in the production process lead to high disruptions, investments in training become more attractive.

2 - Bullwhip effect in promotional sales. New evidence based on time-varying measurements.

Diego José Pedregal Tercero, Juan Ramon Trapero Arenas

Competitiveness reduction in the supply chains around the Globe due to the bullwhip effect is a problem that most companies have to face. It is clearly seen by the significant effort is being devoted by both practitioners and academics to understand its causes and to reduce its pernicious consequences. Nevertheless, limited research has been carried out to analyze potential metrics to measure it, that typically are summarized in the coefficient of variation ratio of different echelons demand. In this work we propose a new metric based on a time-varying extension of the aforementioned bullwhip effect metric by employing recursive estimation algorithms expressed in the State Space framework to provide at each single time period a real-time bullwhip effect estimate. In order to illustrate the results, a case study based on a serially-linked supply chain of two echelons from the chemical industry is analyzed. Particularly, this metric is employed to analyze the effect of promotional campaigns on the bullwhip effect on a real-time fashion. The results show that, effectively, the bullwhip effect is not constant along time, but interestingly, it is reduced during the promotional periods and it is bigger before and after the promotion takes place.

3 - A general lotsizing problem with uncertain product returns

Guillaume Amand, Yasemin Arda

We consider a single-stage system that produces a range of final products. The demands of the final products are supposed deterministic over a finite planning horizon. Each unit of demand has to be fulfilled at the period that it appears using either the production of that period or the inventory carried over from the earlier periods. The final products can either be manufactured using purchased materials or remanufactured using remanufacturable returned products. For each final product, the manufactured and remanufactured items are perfectly substitutable. The returned products are collected at the start of each period but the quantities obtained are unknown until the collection. The return inventories accumulate as remanufacturable returned items are received. The manufacturing and remanufacturing processes of all the final products are executed on a same machine. In each time period, multiple products can be processed but the total production quantity is limited by the time availability of the machine during this period. Whenever production is switched from one final product to another, a sequence dependent setup cost is incurred and a sequence dependent setup time is consumed from the available time capacity. Different stochastic combinatorial optimization methods as well as dynamic programming methods are proposed, tested and compared.

■ WC-07

Wednesday, 12:30-14:00 - TIC Conference Room 1, Level 3

Engineering Optimization 2

Stream: Engineering Optimization
Invited session
Chair: *Jose Herskovits*

1 - Optimal Design of Canals In Order to Minimize Sedimentation: Preliminary Results

Aurea Martinez, Lino J. Alvarez-Vazquez, Rodriguez Carmen, Miguel E. Vazquez-Mendez, Miguel A. Vilar

In this work we deal with the mathematical modelling and optimization of the processes related to the sedimentation of suspended particles in large streams. In order to analyse this environmental problem, we propose two alternative mathematical models (1D and 2D, respectively) coupling the system for shallow water hydrodynamics with the sediment transport equations.

Our main goal is related to establishing the optimal management of a canal (in our case from a wastewater treatment plant, but also, for instance, from an irrigation network) to avoid the settling of suspended particles and their unwanted effects: channel malfunction, undesired growth of vegetation, etc.

So, we formulate the problem as an optimal control problem of partial differential equations, where we consider a set of design variables (the shape of the channel section and the water inflow entering the canal) in order to control the velocity of water and, therefore, the settling of

particles in suspension. To compute a minimal value of the sedimentation, in this work we propose the use of a direct search algorithm: a modification of the classical Nelder-Mead method.

In this first approach to the problem from the viewpoint of environmental control, in addition to a mathematically well-posed formulation of the problem, we present several preliminary theoretical results and numerical examples for a simple realistic case (using MIKE21 software package).

2 - Minimizing the Urban Heat Island Effect in Metropolitan Areas

Lino J. Alvarez-Vazquez, Francisco J. Fernandez, Néstor García Chan, Aurea Martinez, Miguel E. Vazquez-Mendez

In this work we use a combination of optimization, numerical modelling and optimal control of partial differential equations in order to mitigate the urban heat island effect.

This is a very usual environmental phenomenon where a metropolitan area presents a significantly warmer temperature than its surrounding areas, mainly due to the consequences of human activities. The temperature difference between urban areas and the surrounding suburban or rural areas can reach 5 degrees. These temperature differences are larger at night than during the day, and is strongly marked when winds are very weak. At the present time, urban heat island is considered as one of the major environmental problems in the 21st century as an undesired result of urbanization and industrialization of human civilization.

Mitigation of the urban heat island effect can be accomplished through the use of green roofs or of lighter-coloured surfaces in urban areas, or - as will be addressed in this study - through the setting of large green zones of shade trees inside the city. Implementation of heat island mitigation measures is now a prominent part of environmental political tasks in cities with large population and intensive economic activities.

We introduce a well-posed mathematical formulation of the environmental problem (related to the optimal location of green zones in metropolitan areas), we propose a numerical algorithm for its resolution, and finally we present several numerical results.

3 - Design of Thermally Actuated Compliant Mechanisms with the SERA (Sequential Element Rejection and Addition) Method

Vegueria Estrella, Cristina Alonso, Ruben Ansola, Osvaldo Querin

Thermally actuated compliant mechanisms are those onto which thermal loading is applied as input load and their actuation is then based on the thermal expansion of the material. These devices have undergone considerable development since the introduction of the field of Micro Electro Mechanical Systems (MEMS). Originally accomplished by trial and error methods, researchers took an interest in the systematic design of this type of compliant mechanisms by means of topology optimization techniques. The aim of this work is to extend the SERA method for the design of basic thermally actuated compliant mechanisms. This method was applied successfully by the authors to the design of force actuated compliant mechanisms, and the formulation presented here is an extension where the objective is to maximize the output displacement of the mechanism under a constraint in the target volume fraction of material. As a first approach towards more complex electro thermal compliant mechanisms, in this work a uniform heating of the system produces the actuating thermal strain in the compliant device. The originality of the proposed procedure comes from the consideration of two separate criteria for the rejection and admission of elements where material is redistributed between two different models (real and virtual materials). Two benchmark problems were solved and the optimum topologies of the SERA method agree well with the results obtained by other authors.

■ WC-08

Wednesday, 12:30-14:00 - TIC Conference Room 2, Level 3

MAI: Mapping the future: towards the Internet of Things

Stream: Making An Impact 1 (MAI 1)
Invited session
Chair: *Jacqui Taylor*

1 - Mapping the future: towards the Internet of Things
Jacqui Taylor

In this session Jacqui will introduce the mega trends which will affect individuals, organisations and nations as we move towards a future where 80% of the world's population will be connected online; where Big Data post-Snowden could be contentious and divisive; where the Internet of Things requires an understanding of a new way of communicating with customers and citizens we haven't yet met.

Jacqui will take you on a journey beyond Big Data through Smart Cities and into the Internet of Things. She will share some of the projects her web science company have delivered, and the impact these have had across organisations, nations and globally.

This will set the context for a discussion of the consequences of these developments for professionals working in OR, analytics and data science.

An exciting future beckons for all of us who love to work with data. This workshop is for anybody who would like to explore that future.

■ WC-09
Wednesday, 12:30-14:00 - TIC Conference Room 3, Level 3

MAI: What works: OR for policy design

Stream: Making An Impact 3 (MAI 3)
Invited session
Chair: *David Lowe*

1 - What works: OR for policy design
David Lowe

This workshop will be run by the UK OR Society's Special Interest Group on Public Policy Design. It will provide an opportunity for practitioners to share insights with regard to how their practice has supported policy making in the public sector and/or other sectors. The workshop will comprise a set of informal presentations delivered by the practitioners themselves (using a standard quad format to capture: Purpose; Context; Method; and Outcome) to be followed by a facilitated discussion to identify lessons and other key learning points across the case studies presented.

■ WC-10
Wednesday, 12:30-14:00 - TIC Conference Room 4, Level 3

OR in Agriculture I

Stream: OR in Agriculture, Forestry and Fisheries
Invited session
Chair: *LluisM Pla*

1 - Optimization Models for Planning Harvest Season in Apple Orchards
Marcela Gonzalez-Araya, Wladimir E. Soto-Silva, Javier Gomez-Lagos, Diego Caroca-Jara

Optimization models to support planning harvest season in apple orchards are developed. The models seek to minimize the costs associated to labor, resources, machinery and loss of fruit quality during an apple harvest season. The difference between models is the treatment of harvest calendar in order to reduce days where an orchard is harvested. The models were applied to an apple orchard of Maule Region, Chile.

2 - Integrated Production and Distribution Planning in Multi-Product Dairy Supply Chains
Armando Guarnaschelli, Hector Salomone

In this work the production and distribution planning for a real-world dairy supply chain is addressed. A planning model is proposed to account for production and distribution of Cheese, Yogurt, Powdered Milk and UHT Milk product families across a two stage Supply Chain. The model encompasses the activities of raw milk processing into dairy products through the definition of production campaigns and balances the utilization of raw milk supply between different product families. Distribution of products is done through a set of nine distribution centers, the model defines replenishments and truck shipments of products for each of them. As raw milk, yogurt and cheese are refrigerated and have relatively short shelf-life, a special modeling approach is used to account for it at factory and distribution centers inventories. As the numbers of SKUs grows, the complexity of the model grows as well, therefore a solving strategy is included. Finally, a case study for validation and illustration of the features of the planning model is presented.

3 - A hierarchical planning scheme based on optimization models and column generation method for agriculture planning
Victor M. Albornoz

In this work we propose a hierarchical planning scheme that based on integer linear programs and a given decomposition method provides a powerful tool that contributes to obtain an efficient solution for the managing zone delineation and crop planning problems in agriculture. In agriculture, the spatial variability of soil properties is one of the most important aspects that determine productivity and crop quality. Delineating the field into site-specific management zones allows to provide a relative homogeneous partition of each field with respect to a given soil parameter. First, we present a new strategy for solving an integer linear programming model that minimizes the number of zones, for a given value in the limit of the homogeneity within the management zones, by using the column generation method. Then, we introduce an integer programming model to decide which crops to plant on each of the management zones. This task must be made by taking into account the water resources, the properties of the soil, historical prices, estimations of the weather, etc. The results achieved with this methodology, conclusions, and possible extensions of this research will be presented.

4 - Conditional Value-at-Risk in Stochastic Programs for production planning of pig supply chains
LluisM Pla, Esteve Nadal, Antonio Alonso-Ayuso, Victor M. Albornoz

In classical two-stage stochastic programming the expected value of the total revenue is maximized. Planning models along a time horizon have proved to be very effective in supporting agricultural decisions. This is so also for production planning in pig supply chains. Recently, mean-risk models are expanding beyond the mathematical finance area where these models have been studied for decades. Hence, we consider Conditional Value-at-Risk as risk measure in the framework of two stage stochastic integer programming. Pig production depends on the uncertainty of prices that pigs can be sold and the number of pigs a sow can wean. In this context, risk management in a risk averse environment should be considered. The resulting stochastic model is then converted into a mixed-integer linear Deterministic Equivalent Model using a compact representation, where the probability distribution is discrete and finite. The paper in a first stage explores structure, computational time, time horizon, and quality of computational results for this class of models.

5 - Conditional FDH Efficiency, Income Dispersion and Market Imperfections: The Case of the Brazilian Agricultural Census of 2006
Eliane Gomes, Geraldo Souza

In this article, we assess the effect of market imperfections and income inequality on rural production efficiency. The analysis is carried out using the notion of stochastic conditional efficiency, computed in terms of free disposal hull (FDH) efficiency measurements. FDH and conditional FDH are output oriented with variable returns to scale and are evaluated for rural production at county level, considering as output the rank of rural gross income and as inputs the ranks of land expenses, labor expenses, and expenses on other technological factors. The conditional frontier is dependent on gross rural income dispersion and market imperfections resulting from credit, technical assistance, and environmental, social and demographic aggregated indices. The econometric approach is based on fractional regression models and generalized method of moments. The method is robust relative to the endogeneity of some of the covariates and the correlation induced by the efficiency computations. Overall market imperfection variables act reducing performance, and income dispersion is positively associated with technical efficiency.

■ WC-15

Wednesday, 12:30-14:00 - TIC Conference Room 6&7, Level 3

Sourcing and Ordering

Stream: Supply Chain Management
Invited session
Chair: *Morris A. Cohen*

1 - Modeling of Supply Chain Contracts with Price-dependent Demand
Petr Fiala

Supply chain is a decentralized system where material, financial, information and decision flows connect members. Double marginalization is a well-known cause of supply chain inefficiency and the problem occurs whenever the supply chain's profits are divided among two or more members and at least one of the members influences price-dependent demand. Supply chain contract is a coordination mechanism that provides incentives to all of its members so that the decentralized supply chain behaves as the integrated one. When the demand is stochastic than the newsvendor model can be applied. The newsvendor model is not complex, but it is sufficiently rich to study important questions in supply chain coordination. In a standard newsvendor problem the price is assumed to be fixed. The aim of this paper is to analyze contracts for the combined problem of supply chain coordination with price-dependent stochastic demand. The proposed contract for supply chain coordination with price-dependent stochastic demand has desirable features. The supply chain is fully coordinated. Flexibility to allow any division of the supply chain's profit is managed by the selected parameter in the setting of the wholesale price and the buy-back price. It has relative advantages in implementation. The supplier needs to monitor the price only, not the quantity sold. The analysis of the simple cases of contracts gives recommendations for more complex real problem.

2 - Group-buying Strategy with Suppliers' Competition
Lei Guan

Group buying price (GBP) mechanism is a useful pricing mechanism in online sale. In this article, I consider the situation that there are more than one supplier in the market, and one of them uses GBP to sell products. I first discuss the retailers' ordering strategy, and then study how the supplier should set the GBP price curve. The conclusion shows that to beat the fixed price, the supplier should not use a small slope price curve. And retailers' group buying is not always better for the supplier.

3 - Volume Incentive Through Performance-Based Allocation of Business
Liping Liang

Buyers want their suppliers to make efforts to improve performance in the delivery of products and services, but the effort is costly and often unobservable to the buyers. A common practice for inducing high-level supplier performance is to source from multiple suppliers and strategically allocate business based on their past performance. To investigate the design of such performance-based volume incentive schemes, we consider a buyer's dual sourcing problem in a dynamic principal-agent setting. We find that, to maximize suppliers' competition over time, the optimal allocation scheme should involve the suppliers' current shares of business and is generally not a simple rank-order tournament or winner-take-all allocation. The optimal scheme allocates business according to each supplier's performance relative to their respective optimal performance target, and may not reward the better performer a larger share. A simple way to achieve near-optimal results is the use of "handicapped rules" that can significantly outperform simple first-past-the-post rules.

4 - Manufacturing Sourcing in a Global Supply Chain: A Life Cycle Analysis
Morris A. Cohen, *Shiliang Cui*

Many manufacturing firms in developed economies are re-examining the structure of their global supply chain sourcing strategy in response to current uncertainties. For decades, a dominant strategy has been to outsource to low cost suppliers. This has led to the transfer of manufacturing jobs and development activities out of the U.S. and Europe, and into low labor cost countries such as China. In recent years, however, this trend is being challenged by some companies to re-shore manufacturing back to the U.S. or Europe, or to near-shore manufacturing to Mexico or Eastern Europe. In contrast to traditional analysis where

labor cost savings are evaluated versus transportation costs, we propose a comprehensive stochastic model framework for this global sourcing location decision process that incorporates a full product life cycle perspective, i.e., product design, manufacturing, demand fulfillment, and after-sale service support. We derive optimal global sourcing strategies in order to test the validity of competing theories, and find that (i) Government policies such as lower corporate tax rates and greater financial subsidies can have a major positive impact on sourcing decisions; (ii) Technology developments (such as enhanced automation) can negate a landed cost disadvantage based on labor and variable inputs; (iii) Consideration of the capability to develop new products and higher service standards can override cost considerations in making sourcing decisions.

■ WC-17

Wednesday, 12:30-14:00 - TIC Conference Room A, Level 9

Supply Network Risk 2

Stream: Supply Network Risk and Resilience
Invited session
Chair: *John Quigley*

1 - A Bayesian Network Model with Epistemic Uncertainty: Analysis of a Medicine Supply Chain Risk
Lesley Walls, *Kanogkhan Leerojanaprapa*, *Robert van der Meer*

To effectively manage risk in supply chains, it is important to understand the interrelationships between events that might affect the flow of material, products and information. We present a quantitative modelling process using Bayesian Belief Networks to represent probabilistic dependency relationships between events. A visual modelling process, grounded in Bayesian Network theory and the decision context of supply chain risk management, is developed to capture the knowledge and probability judgements of relevant stakeholders. Building causal maps provides a good basis for translating stakeholder cause-effect knowledge about possible events into a formal graphical probability model. A protocol for eliciting subjective probabilities from relevant stakeholders to quantify the state of knowledge uncertainties about risk events has been developed and applied. The modelling process has been evaluated through in in-depth case for the hospital medicine supply of NHS Greater Glasgow and Clyde. Working in collaboration with relevant stakeholders with expertise in all or part of the medicine supply chain, a model has been developed and their perceptions about the process and results have been analysed. We find that the Bayesian Network model of the medicine supply chain has provided insight into risks not captured by conventional risk management methods and it supported deeper understanding of risk through exploration of modelling scenarios. Analysis of stakeholder evaluation.

2 - Dynamic Bayesian Network Modelling of Supply Chain Resilience: Learning from Multiple Industry Cases
Mouhamad Shaker Ali Agha, *Robert van der Meer*, *Lesley Walls*

While there is growing interest in supply chain resilience, conceptualization of the main constructs is discussed at a high level in the literature. We aim to learn more about what supply chain resilience means through modelling, specifically using Dynamic Bayesian Networks (DBNs). DBNs are directed acyclic graphs for reasoning under uncertainty through time. A DBN is capable of using partial knowledge about one variable to update the uncertainty about other variables in the model. In principle, DBNs present a possible model class for analysing resilience because they can capture the dynamic uncertain behaviour of a supply chain due to the effects of potential hazards. Between 2013-5 we have conducted multiple cases for four distinct manufacturing and retail supply chains with focal companies based in the UK, Canada and Malaysia. We present the characteristics of each chain and the insights gained through application of our DBN modelling protocol. Our analysis has generated better understanding of the relative importance of resilience enablers reported in the literature and the propagation of uncertainties on predictions of resilience under different risk scenarios. Reflecting on our modelling methodology has generated insights into the benefits and limitations of DBN for modelling supply chain resilience.

3 - Hybrid Strategy with a Second-order Chance Under Demand Uncertainty and Competition

Liu Yang, C.t. Ng, Yong-Pin Zhou

This paper investigates a firm's hybrid strategic deployment in a competitive market with demand uncertainty and two chances to make production order: before and after demand realization. There are two types of production capacities: stable and responsive. Given an organizational scale, we show that the hybrid production strategy enhances a firm's responsiveness to various demands in a monopoly market. We then examine the impacts of asymmetric organizational scales of firms on their production strategies in a competitive oligopoly market. We demonstrate that capitalizing the second-order chance requires a certain level of organizational scale. We then explore a firm's capacity policy and find that as the market expands, the firm will enlarge its organizational scale and pay more attention to stable capacity investment; when the market becomes more uncertain, the firm tends to invest more in responsive capacity to enhance its ability of hedging against the wild extreme of demand fluctuation. Interestingly and surprisingly, we find that the two strategic decisions have complete sensitivity to competition intensity, due to their different roles in determining a firm's capacity policy.

4 - Generalized Modelling of Supply Networks

Alan Champneys, Thilo Gross, Lucinda Chambers, Lars Rudolf

To model a multitude of suppliers connected by the flow of products, money, or information the concept of supply networks is a common tool. Understanding dynamics on such networks enables to optimize product flows, to minimize risks, and reveal potential sources of instability. The investigation of such dynamics typically faces two major obstacles. First, networks are commonly large and heterogeneous which brings the necessity for detailed information from all parts of the network. Second, information on suppliers is often commercially sensitive and large parts of the network will remain invisible to an observer. Here we utilize the method of generalized modelling to approach this contradiction and to reveal determinants of stability in complex supply networks. Generalized modelling is a technique introduced in ecological systems and entails the assumption of continuous time flows across an integrated network. The method postulates a steady state situation and because interdependencies of production, supply and information flow on the network are unknown, the method assumes general functional forms. The key is to parameterise potential interdependencies between functions and variables based solely on the topology of the network. Application of the method reveals factors that increase or decrease the system stability. In particular a self-limitation in production at specific key elements in the network is in general stabilizing.

■ WC-18

Wednesday, 12:30-14:00 - TIC Conference Room B, Level 9

Inventory Models

Stream: Production and the Link with Supply Chains
Invited session
Chair: *Lionel Amodeo*
Chair: *Gonzalo Enrique Mejia Delgadillo*
Chair: *Matthieu Godichaud*

1 - Product form solution in Two Priority Queueing- Inventory System

Lakshmy Balakrishnan, Krishnamoorthy A., Dhanya Shajin

In this paper we analyse two single server, lost sales (S-1,S)queueing-inventory systems with two demand classes - high priority and low priority. The service of non-priority customers are preempted with the arrival of high priority customers. We compare two different models-one in which,when there is no priority customer present but there is positive inventory,an arriving low priority customer joins the system and in the other case, low priority customers do not join the system only when the onhand inventory is zero. In the first model we obtain stochastic decomposition of the system.On the contrary this property is lacking in model 11. We investigate the behaviour of both these queueing-inventory systems. Several performance measures are evaluated.Numerical illustrations of the systems behaviour are also provided. An optimisation problem of interest of both models are discussed through an example.

2 - An inventory model for optimal ordering quantities of a generic and an original drug

Elif Elcin Gunay, Ufuk Kula

We consider a common problem faced by pharmacies: To decide on the optimal inventory levels, and hence ordering quantities of fully substitutable generic drugs. Usually, there are several brands of generics to treat a condition. Since storing all generics and the original increases the stock holding costs, pharmacies can hold only several types of substitutable original brands and generics. However, some type of customer accept to buy substitutable products (Type I customers) and some reject and insist on to buy the same drug that doctor presribed (Type II customers). Drugstore can fulfill the demand of Type I customer as long as it has any type of substitutable products. On the other hand, Type II customers show different behavior when offered a generic: They decide to fill the prescription, which may contain some other drugs too, at some other store. In our study we consider the problem of deciding optimal inventory levels for a generic and an original brand by analyzing the sales data of a pharmacy and develop a discrete-choice model to model customers' behavior and develop a model that guarantees a certain customer service levels for type I and type II customers while maintaining optimal inventories for the generic and the original brand. We also perform a numerical study to show how stock quantities change according to the proportion of customer types and service level.

3 - Optimizing stock levels in multilocation rental systems with shipments from a support warehouse

Gerlach Van der Heide, Kees Jan Roodbergen, Nicky Van Foreest

We consider a rental system with multiple locations and a support warehouse. The support warehouse is a low-cost storage facility used for shipping stock to locations in response to stock-outs. Such support warehouses are used in practice by public libraries, tool rental companies, and spare parts service providers. The locations and the warehouse replenish inventory using one-for-one base stock policies. Demand is partially backordered. We optimize the stock levels for all stocking points in this system. Bounds on the optimal stock levels are derived from a single location single warehouse decomposition. An accurate approximation using queueing models is provided to determine costs of given stock levels. The bounds and approximation give rise to an efficient heuristic for obtaining near-optimal stock levels. In a sensitivity analysis the stock levels are evaluated under decreasing demand. The policy gradually shifts from predominantly stock at the locations to predominantly stock at the warehouse. A numerical experiment indicates that the warehouse is most valuable for rental systems with low demand rates, low shipment costs, and a high number of locations.

4 - The analysis of continuous (s,S) policies with Markovian Correlated Demand

Walid Nasr, Bacel Maddah

This work considers the realistic and widely applicable case where customer demand is dependent on external environmental factors which result in an auto-correlated and possibly bursty demand process. A Markov Modulated Poisson Process (MMPP) is utilized to model the demand process where the corresponding embedded Markov Chain represents the state of the environment. The main focus of the literature on inventory systems with Markovian demand is on proving the optimality of dynamically changing (s,S) policies. The existing approaches to calculate the state-dependent parameters of (s,S) policies can be computationally prohibitive. The main contribution of this work is proposing computationally efficient numerical techniques to evaluate the expected cost from a given dynamic (s,S) policy coupled with an effective optimization technique to identify cost saving policies. An efficient optimization heuristic is presented and compared to the commonly used approach of approximating the demand-count process over the lead time with a Normal distribution. An investigation of the MMPP demand process is considered where we quantify the impact of variability in the demand-count process which is due to auto-correlation.

5 - A joint pricing and replenishment policy for perishable products with fixed shelf life and positive lead times

Konul Bayramoglu

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Most of the existing inventory models in the literature are based on the assumption that the items have infinite shelf life and do not deteriorate no matter how long they stay on the shelf. However this assumption may not be applicable in many situations since there are also many types of products with limited shelf lives. In the inventory literature stored items with fixed finite lifetimes are usually referred to as perishable items. Examples of perishable products include fresh foods, medical products, whole-blood units, packaged chemical products and photographic films.

In this study, we consider the joint pricing and ordering policy, (Q,r,P_1,P_2), for an inventory model with perishable items, with constant shelf lives and positive lead times. The demand process is assumed to be Poisson. If there is a single batch on hand, the items in a batch are sold at price P_1. If there are two batches in stock, the items in the older batch are sold at price P_2, where P_1 > P_2. The younger batch is not sold until the older one is totally depleted. Although the shelf lives are constant, the sequence of remaining shelf lives of the items at the instances where stock level hits Q, is a random sequence. The limiting distribution of this sequence is obtained and the analytical derivations of the operating characteristics of the model is based on this limiting distribution. Numerical results are also presented.

■ WC-25

Wednesday, 12:30-14:00 - John Anderson JA3.14 Lecture Theatre

Global Optimization Algorithms and Applications

Stream: Global Optimization
Invited session
Chair: *Eligius M.T. Hendrix*
Chair: *Leocadio G. Casado*

1 - Optimization of the heliostat field layout in a Solar Central Receiver System by using evolutionary algorithms.

Nicolás Calvo Cruz, Juana López Redondo, Manuel Berenguel, Pilar M. Ortigosa

In Solar Central Receiver Systems (SCRS), the solar radiation is firstly concentrated and reflected by an heliostat field onto a receiver at the top <of a> tower, and then in the tower the very dense solar power is translated into thermal power to generate electricity. The heliostat field is generally the most important central subsystem in terms of initial investment as well as energy losses. Therefore, the design and optimization of the heliostat field layout are very important. The problem to optimize can be focused on different objectives such as selecting the best layout to maximize the collected solar energy or minimizing the cost of that energy. Several factors that influence in the capture and transmission of the energy have to be considered as the reflectivity of the mirrors, cosine factor due to the incident angle of the Sun on the heliostats, atmospheric attenuation between the heliostats and the receiver, shadowing and blocking effects and spillage of the flux around the receiver aperture. In this work, a model of the objective function to be optimized is presented, where the heliostats are considered to be able to track the Sun at every instant. Then a hybrid evolutionary algorithm has been implemented to find the optimal layout of a SCRS that produces the maximum annual collected solar energy. Results are compared to the ones provided by other authors in order to measure both the optimization algorithm and objective function model efficiency and effectiveness.

2 - Parallelization of the Non-Dominated Sorting Procedure

Gloria Ortega, Ernestas Filatovas, Ester M Garzon

Evolutionary multi-objective optimization algorithms aim at finding an approximation of the entire set of Pareto optimal solutions. In the case of complex problems with many objectives it should be done in a reasonable amount of time, therefore parallel versions of genetic algorithms are developed. However, most of the studies are focused on the parallelization of a particular algorithm, and different implementations are proposed. On the contrary, in our research we aim to speed-up the most time consuming procedure - non-dominated sorting, that is used in several popular multi-objective genetic algorithms. Two versions of non-dominated sorting procedure are developed: (1) multi-core version (based on Pthreads); and (2) GPU version (based on CUDA). The

developed versions are experimentally investigated, and suggestions about their usage are presented in this work. Obtained results show that (1) in the case of relatively small number of objective functions the multi-core version has the best results in terms of performance, moreover experiments performed with different number of processors has shown high efficiency of this version; (2) the performance of the GPU version is increasing in the case of large number of objective functions. It is due to fact that massively parallel platforms (GPUs) allow the acceleration of this kind of procedures because they have several advantages for vectorial computation schemes.

3 - Piecewise linearisation of the first order loss function for families of arbitrarily distributed random variables

Alejandro Gutierrez Alcoba, Eligius M.T. Hendrix, Roberto Rossi

The first order loss function is defined as the expected value of a transformation of a random variable. It is extensively used in several application domains, such as inventory control and finance. In general, the loss function does not have a closed formulation and to evaluate it we must rely on numerical approximations. Earlier investigation focussed on linearisation of the function and the normal distribution. We extend the research and discuss the problem of finding an optimal piecewise linearization for the first order loss function for a group of loss functions on random variables chosen arbitrarily. This problem is nonlinear and several local optimal values and plateaus can be found. We also discuss the embedding of a piecewise linearisation of the first order loss function for arbitrary random variables into a MILP model.

4 - On the size of final sub-simplices in regular refinement of the unit simplex

Leocadio G. Casado, Boglárka G.-Tóth, Eligius M.T. Hendrix, I. Garcia

A natural way to define branching in branch and bound (B&B) with a unit simplex as search space is bisection. The consequence of using bisection is that partition sets are in general irregular. The refinement of the regular simplex by regular simplices has the advantage of smaller memory requirements than irregular simplices for large dimensions, because only its center, size and possibly orientation has to be stored, instead of all its vertices. Unfortunately for dimensions higher than three, a regular simplex cannot be subdivided into regular sub-simplices without overlapping.

Previous studies show that it is possible to avoid the evaluation of an already visited region. Numerical results show a significant improvement when division by regular simplices is compared with traditional longest edge bisection in terms of the number of evaluated simplices. A complete search tree was built up to a predefined precision on the size of a leaf sub-simplex. We observed the existence of vertices at less distance than the precision. Therefore, the question of our investigation is how to set the accuracy on the size of the final simplices to avoid such vertices but also satisfying the required precision in the smallest distance between vertices of different simplices.

5 - On solving blending problems by a branch and bound algorithm using regular sub-simplices

Juan F. R. Herrera, Leocadio G. Casado, Eligius M.T. Hendrix

Branch-and-bound is an exhaustive search method to solve Global Optimization problems. The method ensures to find the best solutions within an established accuracy. A mixture design (blending) problem consists of finding the cheapest proportion of each raw material used to manufacture a product. Quality requirements, formulated as linear and quadratic constraints, restrict the search space of the problem. The initial search space is the unit simplex.

The most used division method to divide the simplicial search space in branch-and-bound is the bisection splitting the longest edge. This division produces irregular simplices in the refinement. Division using regular simplices has the advantage of less storage requirements because edges of each subset have the same length. The main drawback of this method is that a simplex cannot be divided without overlapping when the dimension is greater than three. The application of a division using regular simplices to blending problems presents some challenges in order to avoid the evaluation of an already-evaluated region. To achieve this, a new regular simplex generated in a division has to be compared not only with those simplices pending of division but also with those regions already discarded from the search. These comparisons have a computational cost. The question of this work is whether the efficiency of the regular division is better than traditional division methods to solve blending problems by branch-and-bound.

■ WC-26

Wednesday, 12:30-14:00 - John Anderson JA3.17 Lecture Theatre

Large-scale Linear and Convex Programming

Stream: Convex, Semi-Infinite and Semidefinite Optimization
Invited session
Chair: *Marta Velazco*

1 - Decentralized Benders decomposition for block angular Linear Programming problems
M. Aslı Aydın, Z. Caner Taşkın

Benders decomposition is a well-known method that can be used to exploit certain decomposable structures in linear programming problems. The key idea is partitioning the problem into a master problem and smaller subproblems, then solving subproblems iteratively under the direction of the master problem. Hence Benders Decomposition allows decentralization to a certain extent since the master problem acts as a center to direct subproblems. We propose a decentralized decomposition method for block angular linear programs based on Benders decomposition. The main contribution of this study is to allow collaborative subproblems solve the overall problem jointly without involvement of a center.

2 - Variants of preconditioned conjugate gradient methods applied to linear systems arising from interior point methods
Marta Velazco, Aurelio Oliveira, Alessandro Coelho

The searching directions in interior-point method are computed through the solution of one or more linear systems. Such systems are indefinite and can be reduced to a smaller positive-denite system called normal equations. Generally, the normal equations systems are solved by direct methods. Nevertheless, for some classes of large-scale problems, the use of direct methods is impossible because of storage and running-time limitations. In such situations, iterative approaches are recommended. The performance of implementations using iterative methods depends on the choice of an appropriate preconditioner, in particular for interior point methods; the linear system becomes highly ill-conditioned as an optimal solution of the problem is approached. The classical approach adopted to solve the normal equations system is the preconditioned conjugate gradient method. This work discusses two preconditioned versions of the conjugate gradient method for solve normal equations system: Preconditioned Conjugate Gradient-Normal Residual and Preconditioned Conjugate Gradient-Normal Error. These versions, different from the classic version consider the linear system in form of normal equations. The performances of these two versions of the preconditioned conjugate gradient methods are compared with the classic one. The performances of the algorithms are analyzed using performance prole. The result shows that one of these versions is competitive with the classic one.

■ WC-27

Wednesday, 12:30-14:00 - John Anderson JA3.27, Level 3

Vector and Set-Valued Optimization III

Stream: Vector and Set-Valued Optimization
Invited session
Chair: *Elena Molho*

1 - Equilibria in Multicriteria Games with Potential
Lucia Pusillo

Players have often to "optimize' not one but more than one objective and somtimes not comparable, so multicriteria games help us to make decisions in multiobjective problems. We study how far the theory of strategic games with potential (as introduced by Monderer and Shapley 1996) can be extended to multiobjective games or games with vector payoffs. From the notion of Nash equilibrium (NE for short) for scalar games, we go to the notion of Pareto equilibrium (PE for short) for vector games. So from the notion of approximate Nash equilibrium

(NE for short) we go to the notion of approximate Pareto equilibrium (PE for short). We remind that many auction situations lead to games without exact equilibria but with approximate equilibria. Furthermore We give a notion of optimal point for a strategic game based on improvement sets. This new concept generalizes the idea of exact and approximate equilibrium. Some existence theorems are given. Furthermore we will try to answer to the question if a property valid for a maximum problem, can remain valid for the corresponding potential game.

2 - Characterization of Efficient Solutions for Non-Regular Multiobjective Programming Problems. Duality.
Beatriz Hernández-Jiménez, Rafaela Osuna-Gómez, Marko A. Rojas-Medar, Gabriel Ruiz-Garzón

In non-regular problems the classical optimality conditions are totally inapplicable. Meaningful results were obtained for problems with conic constraints by Izmailov and Solodov for the scalar case. They are based on the so-called 2-regularity condition of the constraints at a feasible point. It is well known that convexity and generalized convexity play a central role in mathematical programming in order to get optimality conditions and duality results. In this paper, for a multiobjective problem with conic constraints, we give the concept of vector Karush-Kuhn-Tucker point, get necessary optimality conditions based on the so-called 2-regularity condition of the constraints at a feasible point; and taking in mind Craven's notion of K-invexity function (when K is a cone in Rn) and Martin's notion of Karush-Kuhn-Tucker invexity, a new notion of generalized convexity is defined. With this new notion we get a sufficient optimality condition and prove that the generalized convexity notion defined is both necessary and sufficient to ensure every Karush-Kuhn-Tucker point is an efficient solution. So the efficient solutions are characterized. Dual problems are formulated and duality results are provided. The results that exist in the literature up to now, even for the regular case, are particular instances of the ones presented here.

3 - An Abstract Scalarization Scheme for Quasiordered Sets: Some Applications to Set Optimization
Elena Molho, César Gutiérrez, Bienvenido Jiménez, Enrico Miglierina

The problem of representing a general quasiorder structure on a given set by means of an (extended) real valued function was studied not only in the field of vector optimization but also, for instance, in economic theory. We provide a very general scalarization scheme to obtain minimality and strict minimality conditions via scalarization on any set ordered by a quasi order relation. This scheme is based on order representation and order preservation properties, that relate the sublevel sets of the quasiorder relation and the sublevel sets of the scalarizing map. In the special case of vector optimization, the obtained results reduce to well-known optimality conditions via scalarization and generalize some of them to non necessarily pointed ordering cones. As an application, we consider the scalarization of a set-valued optimization problem, where the objective values are compared through some quasi order relations between sets induced by the original order structure of the objective space. We consider some particular scalarization schemes under the proposed unified approach and we obtain necessary and sufficient conditions for minimality and strict minimality in set optimization. The abstract approach allows us to easily adapt the results to alternative quasiorder structures in set optimization proposed in the literature.

■ WC-28

Wednesday, 12:30-14:00 - John Anderson JA3.26, Level 3

Quadratic Optimization

Stream: Convex Optimization
Invited session
Chair: *Manuel V. C. Vieira*

1 - Polyhedral Approximations of Completely Positive Optimization Problems
E. Alper Yildirim, Gizem Sağol

Completely positive optimization deals with the optimization of a linear matrix function over an affine subspace of the cone of completely positive matrices. Recently, it has been shown that every quadratic optimization problem with a mix of binary and continuous variables can be formulated as an instance of a completely positive optimization problem. Therefore, despite the convex nature of this class of optimization problems, the cone of completely positive matrices is computationally intractable. We discuss polyhedral approximations of completely positive optimization problems. We present our results on the quality of these polyhedral approximations on certain classes of quadratic optimization problems.

2 - Copositive Optimization Based Bounds on Box Constrained Quadratic Optimization
Gizem Sağol, E. Alper Yildirim

Box constrained quadratic optimization problems (BoxQPs) can be formulated as a linear optimization problem over the cone of completely positive matrices in several different ways. We consider two alternative formulations. We study the sequences of upper and lower bounds on the optimal value of a BoxQP arising from two hierarchies of inner and outer polyhedral approximations for both of these formulations.

3 - GMM Estimation for Semi-parametric Models by Conic Optimization: Special Application to Finance
Erdem Kilic, Fatma Yerlikaya Ozkurt, Gerhard-Wilhelm Weber

The well-known Generalized Method of Moments (GMM) estimation methodology has been evaluated in various specifications. We propose a novelty in GMM estimation by introducing Conic Quadratic Programming (CQP). The proposed model builds up a flexible tool to model financial data. In our study, we first derive and explain our model specifications (semi parametric model). We identify the moment conditions, that are satisfied by the unknown parameters of the model. These moment conditions are determined by the implementation of Conic Quadratic Optimization. In order to generalize our model for the process, which has infinite number of observations, we proof that our model conditions are efficient and consistent. It is shown that consistency can be achieved through convergence of the model parameters towards the true parameters. By the help of Tikhonov regularization, we construct a minimum distance measure and identify the conditions under which convergence is achieved. Asymptotic distribution of the CQP-estimated GMM estimator is evaluated based on the variance-covariance matrix. The optimal choice of the weight matrix, which uses the maximum available information, ensures that the optimal variance-covariance matrix is identified. The application of our study is implemented through an estimation that is founded on a panel data set of international stock exchange index time series.

■ WC-29
Wednesday, 12:30-14:00 - John Anderson JA4.12, Level 4

MINLP and its applications to challenging real-world problems

Stream: Mixed-Integer Nonlinear Programming
Invited session
Chair: *David Rey*

1 - Transit route design with limited through traffic using game theoretic techniques
Taso Viglas, David Rey

Designing a transit route such as a bus, train or subway route, can both benefit and hurt certain locations in transport networks. If a location happens to end up near a station, it will see a significant benefit from its use, and typically a significant increase in through-traffic, from other nearby locations. A recent game theoretic result proposed a model for routing flow in multi-hop wireless networks where intermediate nodes decide on relaying traffic based on mutual incentives and have the ability to punish non-cooperating nodes by blocking traffic. This model indicates that there are strong incentives for nodes to collaborate and allow through traffic, as long as it is not more than the traffic the node generates itself, or receives itself. In addition to that, equilibrium traffic can be found by a linear program for multicommodity

network flows that includes inequalities for through traffic. We adapt this model for the problem of designing transit routes in urban networks. We propose a mixed integer programming formulation where the objective is to maximize transit service utility subject to the equilibrium through-traffic constraints. In practice requiring the through constraints to be enforced leads to inefficient equilibrium assignments; hence a solution method is developed to attempt to minimize the distance from equilibrium, along with other goals related to the cost of the traffic assignment.

2 - Intermodal network design: a mixed-integer nonlinear model for costs and emissions minimization
Martine Mostert, An Caris, Sabine Limbourg

Freight transport has particularly grown in the last decades, with the internationalization of business activities. Even if the transport of goods is positive for the economic development, it also leads to negative impacts on the environment.

The promotion of intermodal transport, i.e. the transport of goods using two or more modes of transport, in the same loading unit, without handling of the goods themselves, is one way to reduce these undesirable effects. Intermodal transport development is in line with the objective of the European Commission to transfer 30% of road freight over 300 km to more environmentally friendly modes, by 2030.

Intermodal transport requires the use of intermodal terminals, where the transfer of goods between modes can occur. The location of these terminals is of strategic importance for ensuring intermodal competiveness.

We develop a bi-objective model which tackles the economic and environmental issues of transport, by focusing on costs and CO_2 emissions minimization, and by taking into account three modes: road, intermodal rail and intermodal inland waterways transport. Economies of scale of intermodal transport are considered using nonlinear costs and emissions functions of the weight. Piecewise linear approximations of these functions are used for solving the problem. The Pareto optimal solutions of the bi-objective model are found using the epsilon-constraint method. The model is applied to the Belgian case study.

3 - Stochastic modelling of corporate investment risk using parallel processors
Jonas Spohr, Ralf Östermark

Measuring the financial risk and optimal capital structure of a corporation is at the core interest of the present study. Irregular disjunctive programming problems arising in firm models and risk management can be solved by the techniques presented in the paper. We show that parallel processing has potential to simplify large scale mixed-integer non-linear programming (MINLP) and general disjunctive programming (GDP) problems with non-convex, multi-modal and discontinuous parameter generating functions and to solve them faster and more reliably than conventional approaches on single processors. Parallel processing and mathematical modeling provide a fruitful basis for solving ultra-scale non-convex GDP problems, where the computational challenge in direct MINLP-formulations or single processor algorithms would be insurmountable. We show that the risk surface of the firm can be approximated by integrated use of accounting logic, corporate finance, mathematical programming, stochastic simulation and parallel processing.

4 - Site layout planning in the presence of travel barriers using mixed-integer programming
David Rey, Ahmed Hammad, Ali Akbarnezhad, S. Travis Waller

We address the site layout problem, where the objective is to find the optimal location of a set of facilities based on the assumed travel frequencies among them. In particular, we focus on a variant of the site layout problem where forbidden regions are present. This problem can be applied to construction site layout planning where the footprint of the building(s) under construction is represented by 2-dimensional polyhedral barriers. The aim is to locate the facilities in order to avoid the forbidden area while at the same time minimising the travel frequency-weighted sum of the shortest feasible paths between the facilities while respecting design constraints. This problem can be represented using mixed integer programming. To resolve the problem the 1-norm distance metric is adopted for travel path approximations and facilities locations are denoted by their respective centroids. Furthermore, the non-convex planar space of the construction site is discretised into convex regions based on the geometry of the travel barriers. We propose a two-stage solution algorithm: in the first stage a relaxed model containing only location constraints is solved to allocate facilities to locations. For each location, feasibility cuts are enforced in

the second stage whenever a location happens to hold an infeasible facility configuration. Our approach provides competitive results when compared to a model where no relaxation and no decomposition are conducted.

■ WC-30

Wednesday, 12:30-14:00 - John Anderson JA5.02, Level 5

Queuing Models

Stream: Simulation and Optimization
Invited session
Chair: *Andreas Löpker*

1 - Non-parametric sensitivity analysis of the M/G/1/N with vacations

Karim Abbas, *Takhedmit Baya*, *Sofiane Ouazine*

The vacations queues are often employed to model many real situations such as computer systems, communication networks, manufacturing and production systems, transportation systems and so forth. These queueing models are generally solved at fixed parameter values. However, the parameter values themselves are determined from a finite number of observations and hence have uncertainty associated with them (epistemic uncertainty). In this paper, we consider the M/G/1/N queue with vacations where we assume that the vacation parameter values have uncertainty. This epistemic uncertainty in vacation parameter is not often taken into account in performance evaluation of such model. Therefore, we develop a new queuing model where we suppose that the epistemic uncertainty in the vacation parameter is expressed in the form of the epistemic distribution. So, in such situations, the model output values (as the stationary distribution) have not fixed values, because it is considered as function of random variable. For that, we use the Taylor series expansions approach to estimate the expectation and variance of model output, due to epistemic uncertainties in the model input parameter.

2 - Analysis of a stochastic on/off system before overflow

Andreas Löpker

We study a continuous time stochastic on/off model describing e.g. a fluid reservoir. We assume that fluid is flowing into the system with a constant rate during on periods, while during off periods the outflow rate is proportional to the level. A switch from on to off periods happens after exponentially distributed random times, while the switch from off to on occurs after random times with a general distribution. We study the time at which the content reaches a given level and the total amount of fluid that flew into the system until then. Power series expansions for the mean and Laplace transform of the two quantities are the starting point for the analysis of the asymptotic behaviour as the overflow level tends to infinity.

■ WC-31

Wednesday, 12:30-14:00 - John Anderson JA5.04, Level 5

Algorithms in Continuous Optimization

Stream: Algorithms and Computational Optimization
Invited session
Chair: *Basak Akteke-Ozturk*

1 - The Exact Penalty Map for Nonsmooth and Nonconvex Optimization

Alfredo Iusem, *Regina Burachik*

Augmented Lagrangian duality provides zero duality gap and saddle point properties for nonconvex optimization. On the basis of this duality, subgradient-like methods can be applied to the (convex) dual of the original problem. These methods usually recover the optimal value of the problem, but may fail to provide a primal solution. We prove that the recovery of a primal solution can be characterized in terms of:(i) the differentiability properties of the dual function and (ii) the exact penalty properties of the primal-dual pair. We also connect the property of finite termination with exact penalty properties of the primal-dual pair. In order to establish these results, we associate the primal-dual pair to a penalty map,which is convex and globally Lipschitz, and such that its epigraph encapsulates information on both primal and dual solution sets.

2 - Continuous Global Optimization based on Contractor Programming

Jordan Ninin

Contractor Programming is a methodology which allows to enclose each algorithm in a unify framework, in order to interact heterogeneous formulations or techniques. In this talk, we will present a general pattern based on contractor programming for designing a global optimization solver. This approach is based on Interval Analysis and can deal with problems with a wide variety of constraints. Using Contractor Programming, we will show a user-friendly way to solve problems with non-smooth functions, disjunctive constraints, non-mathematical constraints (such as "stay in an area defined by a polygon") and constraints with quantifiers (such as ForAll and Exists). This approach allows to design, in a single step, a model and a solver for a given problem. This framework is implemented in the library IBEX (http ://www.ibex-lib.org) which is free available. The goal of this library is to give all tools to the users for designing easily the best solver for its own problem.

■ WC-32

Wednesday, 12:30-14:00 - John Anderson JA5.05, Level 5

Index tracking and portfolio selection

Stream: Emerging Applications in Portfolio Selection and Management Science
Invited session
Chair: *Maximilian Adelmann*

1 - Linear Programming Models based on Omega Ratio for the Enhanced Index Tracking Problem

Gianfranco Guastaroba, *Renata Mansini*, *Wlodzimierz Ogryczak*, *M. Grazia Speranza*

Modern performance measures differ from the classical ones since they assess the performance against a benchmark and usually account for asymmetry in return distributions. The Omega Ratio (OR) is one of these measures. Until recently, limited research has addressed the optimization of the OR since it has been thought to be computationally intractable. The Enhanced Index Tracking Problem (EITP) aims at selecting a portfolio of securities able to outperform a market index while bearing a limited additional risk. We propose two mathematical formulations for the EITP based on the OR. The first one applies a standard definition of the OR where it is computed with respect to a given value, whereas the second one considers the OR with respect to a random target. We show how each formulation, nonlinear in nature, can be transformed into an LP model. We extend the models to include real features, such as a cardinality constraint and buy-in thresholds on the investments, obtaining MILP problems. Computational results conducted on a large set of benchmark instances show that the portfolios selected by the model assuming a standard definition of the OR are consistently outperformed, in terms of out-of-sample performance, by those obtained solving the model that considers a random target. In most of the instances the portfolios optimized with the latter model mimic very closely the behavior of the benchmark over the out-of-sample period, while yielding, sometimes, quite larger returns.

2 - A Large-Scale Optimization Model for Replicating Portfolios in the Life Insurance Industry

Maximilian Adelmann, *Karl Schmedders*, *Janos Mayer*

Replicating portfolios are rapidly emerging as an important tool in the life insurance industry for the valuation of companies' liability cash flows. This paper presents a Replicating Portfolio (RP) Model to map life insurance liabilities to a set of candidate assets. We minimize the L1 error between the discounted life insurance liability cash flows and the discounted RP cash flows over a multi-period time horizon for a broad range of different economic future scenarios. We apply two different linear reformulations of the L1 problem to solve large-scale RP

optimization problems and also present several out-of-sample tests to assess the quality of RPs. A numerical application of our RP model to empirical data sets demonstrates that the model delivers RPs with cash flows matching liability cash flows rather closely. We complete the paper with a comparison of running times for the two linear formulations and for different LP algorithms. The numerical analysis demonstrates that our model delivers RPs with excellent practical properties in a reasonable amount of time

3 - Dose the floating required return impact the performance of the portfolio?

Chinghung Hung, Jing-Rung Yu, Paul Chiou, WenKuei Dong

The method to form the portfolio required return affects the asset allocation. The use of a fixed required return in generating portfolio weights reflects investor's expectation but not the dynamics in market. In this study, we use the floating required return generated from each trading day to rebalance portfolio. Using the mean variance (MV) and 1/N strategy as the benchmarks, our study compares performance of popular risk-based portfolio models, including the downside risk (DSR) model, conditional value at risk (CVaR) model, worst-case conditional value at risk (WCVaR) model, relative robust conditional value at risk (RRCVaR) model, Omega ratio model, and linearized VaR model. Differing from conventional MV model, these portfolio models use the loss of portfolio value, but not variance of asset return, to measure risk. To improve the feasibility of the strategies, we model the short selling and transaction costs in the portfolio. The asset allocation is rebalanced by using the rolling window data and by applying multi-period trading simulation. We use the daily data of a wide range of high-liquidity assets, such as the exchange traded funds (ETFs), commodity, energy etc. to perform the simulation. The performance measurements: the realized market value, expected return, Sharpe ratio and Omega ratio are used. Our empirical results show that the portfolios with floating required return outperform the portfolios with fixed required return.

■ WC-33

Wednesday, 12:30-14:00 - John Anderson JA5.06, Level 5

Non-Standard Multiobjective Problems

Stream: Multiobjective Optimization - Methods and Applications
Invited session
Chair: *Richard Allmendinger*
Chair: *Joshua Knowles*

1 - Toward a Methodology of Combining Optimization Models

Stefan Ruzika, Tobias Kuhn

Complex decision making situations usually require the solution of several related optimization problems. These optimization problems are often integrated, interrelated, and interlaced. Nonetheless, it is common to follow a divide-and-conquer approach to be able to cope with complexity and treat the optimization problems separately and sequentially. It goes without saying that this approach typically does not meet the demands of the complex situation in which the optimization models are integrated.

The goal of this article is to get a better understanding of the term "integrative". To this end, we revert the line of thought mentioned above: Given two optimization problems, we analyze several methods of combining and linking them. Relationships between these methods are then analyzed.

2 - Deal Website Selection with Fuzzy TOPSIS Method

Funda Samanlioglu

Selection of the appropriate deal website for shopping online is a complex problem and requires an extensive evaluation process. In this research, as alternative deal websites, Markafoni, Trendyol, Limango, Morhipo, Lidyana, and Hepsiburada are taken into consideration. These websites offer their customers the concept of private shopping online in Turkey and supply world-famous exclusive fashion brands of apparel, shoes, cosmetics, accessories, sporting goods, toys, technology and decoration products in different categories with various deals and discounts. These decision alternatives are evaluated with

respect to several benefit criteria such as shortage of delivery times, number of members, ease of payments (the number of installments permitted), variety of products, reliability of transactions, and variety and efficiency of deals and discounts. As the multiple attributes decision-making method; a fuzzy TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method is implemented in order to evaluate and rank these major deal websites in Turkey. In this method, linguistic preferences, specifically the ratings of alternatives, and importance weights of criteria, are converted to triangular fuzzy numbers and used in the TOPSIS calculations.

3 - Parallel Hybrid Multiobjective Derivative-Free Optimization in SAS

Steven Gardner, Joshua Griffin

We present enhancements to a SAS high performance procedure for solving multiobjective optimization problems in a parallel environment. The procedure, originally designed as a derivative-free solver for mixed-integer nonlinear black-box single objective optimization, has now been extended for multiobjective problems. In the multiobjective case the procedure returns an approximate Pareto-optimal set of nondominated solutions to the user. We will discuss the software architecture and algorithmic changes made to support multiobjective optimization and provide numerical results.

4 - What is the Future Trend of Decision-making

T. C. Wong

Many intelligent decision-making tools have been developed over the past few decades. However, the real-life application of these tools is still limited even a high degree of consistency and flexibility of these models are reported. Perhaps, from the decision-makers' perspective, the lack of understanding about the models would be a major source of resistance. Also, the trade-off between gains and dedications associated with the model development as well as implementation would be another bottleneck. In this connection, the future trend of decision-making model development should consider the interaction of the end users and the decision environment. In addition to the transformation of the domain knowledge into decision rules, it is also vital to recognise WHY the users prefer one decision over others under a specific decision environment, and HOW they may change their preferences. With this "learning' ability, such decision-making tool may be able to generate decisions that are not necessarily the optimum but rational from the users' viewpoint. This would increase the user acceptance since the tools would behave more like them. Due to technological development, environmental data can be readily collected and analysed. Hence, a data-driven approach which employs artificial intelligence to uncover the connectivity between key environmental factors and users' preferences should be adopted.

■ WC-35

Wednesday, 12:30-14:00 - Colville C429, Level 4

Energy Planning

Stream: Energy/Environment and Climate (contributed)
Contributed session
Chair: *Paul Jennings*

1 - The Challenges of Maintaining a Long-Term Life Cycle for a Model at the Sellafield Nuclear Site

Paul Jennings, John-Patrick Richardson

The UK National Nuclear Laboratory's (NNL) Decision Science team have been supporting Sellafield Ltd (SL) since 2004 to optimise the usage of the Fuel Handling Plant at the Sellafield site in West Cumbria. The model was developed in WITNESS, with an Excel interface at its front-end. With much of the literature for Discrete Event Simulation covering short-term model use, such as how to build, document and run a model, this presentation will supplement this by focusing on long-term management, and how NNL ensure that the model continues to be fit-for-purpose, current and adaptable. Topics covered include our customer/supplier relationship with SL, how difficulties in ensuring knowledge transfer between analysts have been addressed which has resulted in a standard set of documentation. There has been much debate with the customer over the scope of the model, with more detail added to address new challenges for the facility, resulting in additional

complexity and slower model runtimes. The end is now in sight for the model, with no more Magnox fuel being produced, the last Magnox power station due to close by 2016, and Magnox Reprocessing ceasing to operate. This brings new challenges on assessing investment in the model against a known end of life. During this journey from initial model build to the current day, a number of queries have been investigated which will be discussed to show the range of issues that the model can address.

2 - Rapid-prototype modelling of energy technologies in their respective 'natural ecosystem'
Richard Kiefer

RWE is the largest electricity producer in Germany and one of the largest in Europe. Since the electricity sector has traditionally been characterized by large investments and long pay-back periods, decisions were based on long-term expectations for the electricity system. To gain these, fundamental optimization models of national electricity systems have been used. However, new trends in the energy system drive the need for much more flexible and quick modelling: On one hand, accelerating convergence of energy sectors needs reflection in the modelling abilities. On the other hand, incentives in today's German energy system favour decentralised investments which can only be predicted analysing the efficiency in their 'natural ecosystems', i.e. systems of a suitable scale. At RWE R&D we use an intuitive and flexible, simplified model able to capture energy systems at many scales and able to spread over several sectors. The infrastructure is written in GAMS, the actual system modelling can be done via Excel based on a "back-of-the-envelope'-type graphic construction. Two example questions and their rapid modelling are presented, as well as some of the infrastructure and results.

3 - Application of GA Methods in the Design of a Stirling Engine-based Micro-CHP System
Ana Cristina Ferreira, Jose C. Teixeira, Senhorinha Teixeira

Combined Heat and Power, CHP, represents the combined production of electric and thermal energy, from a single primary energy source. It is a well-established technology, which has important benefits and has been noted by the European Community as one of the first elements which saves primary energy, reduces greenhouse gas emissions when compared to the reference separate production by large thermal power stations. High efficiency CHP systems based on Stirling engine was considered for optimization using performance and costs criteria. A thermal-economic model was developed so that the output power and thermal efficiency of the Stirling system could be studied. The main objective of this work is the optimization of a solar renewable-based cogeneration system able to suppress both thermal and electrical needs, by using numerical optimization. A Stirling engine is optimized by trying to disclose the best operational parameters for the Stirling engine, by using genetic algorithms through a software-code developed in the MatLab®. The choice of a metaheuristic algorithm is due to the complexity of the mathematical model that describes the thermodynamic relationships. The work discusses different combinations and number of decision variables, and analyses their relevance in the thermal-economic output. The objective function corresponds to the balance between the incomes and costs. Results show that the the regeneration process efficacy has a great effect in the engine performance.

4 - Determination of Materials that have Renewable Energy Potentials and Design of Test Set to Optimize the Parameters that are Related to these Processes
Gulsen Yaman, Ramazan Yaman, Halil Sinoplugil

Identification of materials which can be used for renewable energy (treated paper, wood, plastics, composites etc.) and identification of the parameters that are appropriate for the processes of energy resources are important for both commercial and academic consideration. Experimental studies to determine the basic parameters, and performing these experiments for this purpose are inevitable. Therefore the design of the test set is an important process in order to carry out the experiments easily and significantly. The aim of this study are to perform pyrolysis experiments for renewable energy materials, review the processes of the identification of parameters, explain and evaluate a design for this purpose.

◼ WC-37

Project Management and Scheduling

Stream: Project Management and Scheduling
Invited session
Chair: *Erik Demeulemeester*

1 - A Multi-Objective Approach to Multi-Mode Multi-Project Scheduling under Mode Duration Uncertainties
Gündüz Ulusoy, Emre Arda Sisbot, Can Akkan

We investigate the multi-mode multi-project resource constrained project scheduling problem under mode duration uncertainty. Dealing with uncertainty and avoiding unplanned disruptions become extremely important particularly in multi-project settings. We assume a multi-objective setting with the objectives of minimizing both the multi-project makespan and the total sum of the absolute deviations of the scheduled starting times of activities from their earliest starting times found through simulation. We develop a multi-objective genetic algorithm designated here as H-Moga. Deterministic version of the problem is solved for minimum makespan using a genetic algorithm, which is then employed to assess H-Moga's performance. Three performance measures are used for that purpose. Computational studies are performed for different problem sets in various parameter settings comparing H-Moga against deterministic schedules. H-Moga strictly outperforms deterministic solution in over 83% of the evaluated instances. In the remaining instances H-Moga generates schedules that are not dominated by the deterministic approach. A reasonable run time is achieved considering the difficulty of the problem.

2 - Resource-constrained project scheduling with overtime
Andre Schnabel, Carolin Kellenbrink

Jobs scheduled in the conventional resource-constrained project scheduling problem (RCPSP) consume renewable resources during their execution. Thereby, it is often assumed that each of these resources has a constant capacity throughout the planning horizon, which must not be exceeded. In practice, the usage of additional capacities can be part of the decision problem. For that reason, we extend the classical RCPSP by a decision on the usage of overtime with associated penalty costs (RCPSP-OC).

In order to solve problem instances of practically relevant size, we develop heuristic solution methods. We present genetic algorithms using different solution encodings and corresponding schedule generation schemes. Some of these genetic algorithms adapt ideas from standard RCPSP methods, by not always scheduling jobs as early as possible. Others however are based on methods for minimizing the resource utilization (e.g. for the resource renting problem). Those methods can be adapted for solving the RCPSP-OC by determining promising project deadlines and exploring the set of schedules observing these deadlines for minimal overtime costs. Additionally, we evaluate the effectiveness of solving the RCPSP-OC using the proposed genetic algorithms in a comparative study.

3 - Bidding for public-private partnership projects: a risky competition
Dennis De Clerck, Erik Demeulemeester

Public-private partnerships are the prototype example that construction projects become larger and riskier. Therefore, it is essential to look into bidding under large contingencies. Contractors need to carefully prepare the project proposals before entering the tendering procedure. The bid preparation is expensive, but could result in higher quality proposals and more accurate estimations of the actual project cost. Consequently, besides determining an appropriate mark-up that reflects the risk premium and the profit margin, the contractors also decide how much effort to put into the bid preparation process. Our research aims to develop a competitive bidding model that characterizes the equilibrium bidding behavior of the contractors with respect to the number of bidders and the magnitude of the risk. Moreover, we are interested in the dynamics of the bidding behavior when there are future project opportunities. Through the Markov perfect equilibrium concept, our numerical experiments indicate that the introduction of a pipeline of projects in the future results in fiercer competition from a mark-up perspective. Nevertheless, the bid preparation efforts will highly depend on the transferability of the knowledge to future projects. We

also present the results of a laboratory experiment with 180 business students bidding on high-risk projects and show that the participants consistently underbid with respect to the theoretical equilibrium predictions.

■ WC-39

Wednesday, 12:30-14:00 - Colville C405, Level 4

Preference Learning II

Stream: Preference Learning
Invited session
Chair: *Salvatore Greco*

1 - Using polynomial marginal utility functions in UTADIS

Olivier Sobrie, Nicolas Gillis, Vincent Mousseau, Marc Pirlot

UTADIS is a MCDA disaggregation procedure used for sorting problems in which categories are ordered. It takes as input a set of assignment examples evaluated on multiple criteria and learns a model restoring as much examples as possible. The resulting model is composed of a marginal utility function per criterion and global utility thresholds delimiting the ordered categories. Each marginal utility function is monotone in the criterion domain. In UTADIS, marginal utilities have a piecewise linear form. Using piecewise linear functions limits the flexibility of the model and leads to functions which are not natural close to the breakpoints. We propose a new approach which consists in replacing the piecewise linear functions by polynomials. Some results on real and artificial datasets are presented.

2 - Optimal and suboptimal strategies for eliciting the set of sufficient coalitions of criteria

Ersek Eda, Marc Pirlot

Some preference models, such as these underlying the ELECTRE methods, rely on rules, which basically say that an alternative is preferred to another if it is at least as good on a sufficient coalition of criteria and not excessively worse on any of them. The number of possible families of sufficient coalitions of criteria grows incredibly fast with the number of criteria. These numbers are known as the Dedekind integer sequence. Therefore, eliciting the set of sufficient coalitions of criteria in a given decision problem requires appropriate strategies. In this work, we present optimal and suboptimal algorithms for questioning a decision maker about sufficient coalitions of criteria. We examine in particular the impact of different types of additional information such as the knowledge of an importance order on the criteria.

3 - Preference learning in evolutionary multiobjective optimization guided by Choquet integral preference model

Roman Slowinski, Juergen Branke, Salvatore Corrente, Salvatore Greco, Piotr Zielniewicz

We present an interactive evolutionary multiobjective optimization method that learns user's preferences from pairwise comparisons of some non-dominated solutions in successive generations. When choosing the mathematical form of the preference model to be learned, one faces the usual dilemma: if the preference model is too simplistic (say, linear), it is unlikely to be able to represent adequately the user's preferences expressed in interactions; on the other hand, if the preference model is too versatile, a lot of preference information is required from the user to narrow down the model's parameters to a useful degree, i.e., such that the preference relation implied by the model is sufficiently richer than the dominance relation. For this reason, we propose a method called NEMO-IICh that adapts to the complexity of user's preferences in the course of successive generations. It starts with a linear additive model, and switches to 2-additive Choquet integral, once the linear additive model is not able to represent the cumulated pairwise comparisons supplied by the user. Computational experiments with continuous and combinatorial multiobjective optimization problems prove a good convergence of the proposed method to the most preferred region of the Pareto front for a simulated artificial user.

4 - Combining Data Mining Techniques and Multi-Criteria Method

Glauco da Silva, Marta Barros, Helder Gomes Costa

By a combination of data mining techniques and multi-criteria methods (Probabilistic Composition of Preferences — CPP-TRI) this paper aims to propose a new grouping of the Brazilian Federation Units (BUF) by main activity of the employed population, the geographical connectivity of BUF is not considered. From a sample based on the last Brazilian census, assuming each of BUF as an instance and each of activities of the employed population as an attribute, the attributes are selected by analysis with filters techniques. Once the attributes were selected, the original classes (regions) are excluded to allow the clustering process; so, the database is subjected to k-means, which generates the initial classes for the CPP-TRI. Based on the similarities and dissimilarities of economic activities of the employed population, evidenced by the cluster formation process with machine learning tool, new groupings are identified and compared with the results obtained by the CPP-TRI method. The BUF classification obtained by CPP-TRI was agreed with k-means about 65% and 30% of instances were allocated in neighboring class. Exploratory analysis of new groups allows increasing the knowledge on the particularities of BUF with quantitative and economic bias base. The identification of new economic blocs, which were hidden when using the traditional models based on geographical criteria, can promote the formation and development of cooperative actions among BUFs.

■ WC-41

Wednesday, 12:30-14:00 - Colville C512, Level 5

Preference Modelling II

Stream: Multiple Criteria Decision Aiding
Invited session
Chair: *Silvia Angilella*

1 - A novel dynamic and social perspective of multiple criteria decision making

Evelina Giacchi, Salvatore Corrente, Alessandro Di Stefano, Salvatore Greco, Aurelio La Corte, Marialisa Scatà

We discuss a Social Decision Making model describing real worlds scenarios in which a population of agents interacts in a network. Each agent takes its decisions considering a set of points of view in a multiple criteria decision making perspective. This model can represent situations of interest in different domains, such as Information and Communication Technology (ICT). Our model has two main features: dynamism and context-awareness. Dynamism refers to evolving preferences due to interactions between agents in the network. The context-awareness, instead, is the knowledge background that the agents take into account in doing their decisions. The evolution of a network will consequently depend on three factors: its initial configuration, the inclination of each agent to be influenced by the other agents in the network and the variability of the context-awareness. Depending on these three factors, the network could oscillate between several configurations or it can move to a fixed configuration that will not be modified anymore. In this new social perspective of multiple criteria decision making, the behaviour of each agent is represented by different parameters whose variation determines the evolution of the network. The proposed model could explain dynamic behaviours in several socio-economics contexts such as fashion economy and housing location.

2 - Weighted Almost Stochastic Dominance

Chin Hon Tan

Stochastic dominance can be used to simplify the decision process by eliminating alternatives that are clearly inferior for a decision maker that is faced with multiple alternatives. However, conventional stochastic dominance rules are unable to reveal the unanimous preferences for the non-risky reward in the St. Petersburg paradox proposed by Bernoulli in 1738. We introduce a new stochastic dominance condition and illustrate how it addresses this issue.

3 - Rules for supplier selection using intuitionistic TOP-SIS

Sunday Omosigho, Dickson E. A Omorogbe

The supplier selection problem entails selecting a number of suppliers from a list of suppliers using many criteria. TOPSIS (Technique for Order Preference by Similarity to the Ideal Solution) is one of the methodologies for solving the supplier selection problem. Among other computations, TOPSIS requires the determination of the positive ideal solution (PIS) and the negative ideal solution (NIS). The PIS is a matrix containing the best ratings for all criteria and all suppliers while the NIS is a matrix containing the worst ratings for all criteria and all suppliers. For each supplier, a similarity measure call closeness coefficient is calculated using the distances of each supplier from the PIS and NIS. These distances are calculated using a metric function. The closeness coefficients are used to rank the suppliers. The best supplier has the smallest value of the closeness coefficients. However, when several metric functions are adopted in some supplier selection problems, contradictory recommendations may be obtain. For example, if A3»A1 means that supplier A3 is preferred to supplier A1, we may obtain A3»A1>A4»A2»A5 and A3»A1»A2»A4»A5 when five suppliers A1, A2, A3, A4, and A5 are compared using two different metric functions. The paper proposes how to resolve contradictions in the ranking of suppliers. Simple and easy-to-use rules are proposed. Examples are given to illustrate the applications of the proposed inference rules for the ranking of suppliers.

■ WC-42

Wednesday, 12:30-14:00 - McCance MC301, Level 3

Case studies in OR/Analytics 5: Analytics

Stream: Case Studies in OR / Analytics
Invited session
Chair: *Sue Merchant*

1 - Mapping the Future towards the Internet of Things
Jacqui Taylor

The speaker will take you on a journey beyond Big Data through Smart Cities and into the Internet of Things. She will share some of the projects her web science company have delivered, and the impact these have had across organisations, nations and globally. She will set the context for the changes the web will bring and the impact it will have on all our careers. This presentation will include how both practitioners and academics can take advantage of these new and developing opportunities.

2 - Using Retail Sales Data to Realign Store Trading Hours
Martin Slaughter

Vodafone UK have a retail network of stores which provide a range of sales, advice and support services to customers of their mobile phone network. Stores originally traded using traditional opening hours but Vodafone were keen to identify if there was evidence to support moves to set trading hours on a store-by-store basis and, if so, what the hours should be for their 300+ sites. Hartley McMaster Ltd used large data sets measuring footfall in stores and sales profiles to correlate customer arrival patterns with sales activity and to develop tools to identify revised store trading hours — constrained by the practicalities of rostering staff — to improve trading efficiency and mirror local and evolving shopping patterns. The store hours of virtually all shops were altered in line with the model recommendations. The trading performance was reviewed 12 months later and trading performance had improved as predicted.

3 - The Use of Process Mining in the Steel Industry
John Albiston, Stephen Thornton, Eddy Van der Geest

Delivery on time or the ability to give the customer want he wants when we promise it, is a key customer satisfaction measure. The steel industry has not got a good record in achieving full compliance in on-time and in full(DOTIF). Several different strategies are deployed to improve our DOTIF, which give some buffers to allowing better delivery to the customer, while increasing flexibility within the steel manufacturing process. Such techniques as MTS/FTO certainly improve delivery performance , but don't necessarily improve the internal reliability of the process. Furthermore, these operational approaches can mask the underlying structural problems which ultimately constrain performance. Over many years analytical techniques have been used to gain insights in to the understanding of the through process chain, including the use of RRS and ABC analysis. Data mining has helped us to

understand and explain much of what is happening, leading to substantive improvement. The complexity of material flows,results in system dynamics which are very difficult to analyse and fully optimise. Tata Steel has recently become aware of a technique called process mining. This promises to give more insights into the flow of material through processes such as the ones described. This presentation will discuss a pilot project to examine the use of this technique to evaluate its potential to give additional insights which we can use to improve our order fulfilment process.

4 - Experiences with Developing a Data Product for Life and Pensions Firms: Mortascoregeo
Colin Stewart

At OR55 in 2013 the author gave a presentation describing a new post-code mortality risk model (now called mortascoregeo) which used only open source data to estimate mortality risk at a local level across the UK. Over the last two years a significant amount of work has been done to get this product to a point where it is ready for launch (as at March 2015). This presentation will tell the story of what had to be done to ensure mortascoregeo is a credible offering for use by Re-insurers and Insurers offering Life and Pensions products. The talk will cover: ● The technical development work needed to make the product perform sufficiently well and the important role that "Big Data' has played in helping us do this. ● The critical importance of having the right team in place to be seen as being credible. ● The collaboration of potential users in design and testing and how we have positioned the product in order to gain and maintain their interest. ● Progress achieved to date and where we hope to be in the future.

5 - Optimisation projects: When Should Pragmatism Trump Optimality?
Paul Edkins

A power company's assets degrade over time, posing an increasing risk of failure. They want to optimise their asset intervention schedule to minimise risk, within budget constraints. Which assets should be replaced/refurbished and when?

One solution might be to select interventions based on the health of each asset and then schedule the interventions in health priority order. However this provides no guarantee of optimal risk reduction.

Another solution might be to formulate a mixed integer program, with integer decision variables for the asset intervened and its year of intervention, and constraints of risk and budget. Then find the optimal risk reduction by allowing the model to select which assets to replace/refurbish and when. But because asset health deteriorates over time, optimising by risk means the greatest risk reduction is achieved by waiting as long as possible before intervening. Is this formulation appropriate or computationally tractable?

Under what circumstances should modellers decide to simplify the optimisation procedure and forego a guarantee of optimality? This presentation will explore this question through a case study, and includes a reflection on how the consulting process helped to answer the question.

■ WC-47

Wednesday, 12:30-14:00 - Graham Hills GH513, Level 5

MAI: Trust me! I'm a modeller

Stream: Making An Impact 1 (MAI 1)
Invited session
Chair: *Ruth Curran*

1 - Trust me! I'm a modeller
Ruth Curran, Emma Frost, Alessandro Arbib

If it isn't one of your greatest fears, it should be: the fear that there is an undiscovered bug in your model. For some (non-OR) UK government modellers this came horribly and very publicly true in 2013: their model's output was challenged by one of the companies affected by the results. It was then shown to be inconsistent with previously published guidance as a result of an error in a spreadsheet and the assumptions underlying it. The cost to the government of the error itself, the judicial proceedings, the delays to investment, and associated consequences has been estimated at £50million.

One beneficial consequence was a major review of modelling in practice, leading to the publication this year of The AQua Book - a handbook of best practice in quality assuring models, from conception to implementation. This workshop, led by one of the people involved

in the AQua Book production, will introduce some of the issues, and recommendations, with practical QA of real models. Participants will have a chance to learn about best practice, and to contribute their own views of how to ensure that trust in their model is well-placed.

■ WC-48

Wednesday, 12:30-14:00 - Graham Hilils GH510, Level 5

Graphs

Stream: Telecommunication, Networks and Social Networks (contributed)
Contributed session
Chair: *Saulius Minkevicius*

1 - Analysis of the Idle Time Model in Computer Networks
Saulius Minkevicius

An open queueing network model in light traffic and heavy traffic has been developed. The probability limit theorem for the idle time process of customers and the probability limit theorem for the virtual waiting time of a customer has been presented in light and heavy traffic conditions in open queueing networks. Finally, we present an application of the theorem - an idle time model from computer network practice. If light and heavy traffic conditions are fulfilled, we prove that an open computer network is idle or busy. Light and heavy traffic conditions are fundamental - the behaviour of the whole network and its evolution is not clear, if these conditions are not satisfied. Therefore, this fact is the object of further research and discussion.

2 - An Optimization-Based Decoding Algorithm for Convolutional LDPC Codes in Communication Systems
Banu Kabakulak, Z. Caner Taşkın, Ali Emre Pusane

In a digital communication system, we send information from one place to another over a noisy communication channel. It may be possible to detect and correct the errors that occur during the transmission if we encode the original information by adding redundant bits. Convolutional low-density parity-check (LDPC) codes, an LDPC code family, encode the original information to improve error correction capability. In practice, these codes are used to decode very long information sequences, where the information arrives in packets over time, such as video streams. We formulate the problem of decoding the received information with minimum error as an integer programming formulation. We investigate exact and heuristic decoding algorithms for the solution. We consider a relax-and-fix heuristic that decodes information in small windows. Our preliminary computational results indicate that our heuristic identifies near optimal solutions faster than CPLEX 12.6.0 in high channel error rates.

3 - Bayesian inference for the reliability of scientific co-authorship networks with emphasis on nodes or researchers
Sandra Cristina de Oliveira, Taiane de Paula Ferreira, Juliana Cobre

A research group may be considered a scientific co-authorship network which may be modeled by a graph G with k nodes and m edges. Researchers that make up this network may be interpreted as its nodes and the connections between agents (represented by co-authored papers) may be considered as its edges. Current study measures the reliability of networks by taking into consideration unreliable nodes (or researchers) and perfectly reliable edges (co-authorship relations). A Bayesian approach to the reliability of a co-authorship network represented by a research group of UNESP registered at CNPq has been proposed, obtaining Bayesian estimates and credibility intervals for the individual components (nodes or researchers) and the co-authorship network. Informative and non-informative priors have been assumed and compared, and the posterior summaries have been obtained by Monte Carlo Markov Chain simulation methods. Results showed the relevance of an inferential approach for reliability of scientific co-authorship networks, noting that the contribution of each researcher is highly relevant for the maintenance of a research group. In addition, the Bayesian methodology was a feasible and easy computational implementation, enabling the incorporation of prior information in the estimation process.

■ WC-49

Wednesday, 12:30-14:00 - Graham Hills GH511, Level 5

Vehicle Routing in Order Picking

Stream: Location, Logistics, Transportation (contributed)
Contributed session
Chair: *Ying-Chin Ho*

1 - The performance of various routing strategies for order-picking operations in a zone-picking warehouse
Ying-Chin Ho, Chih-Feng Chou

Studies have shown order-picking operations account for a large portion of the total operational cost in a distribution warehouse. As a result, distribution warehouses have been investing a great deal of time and effort in finding ways that can improve the efficiency of their order-picking operations. And, finding the right routing strategy for order-picking operations is one of them. The environment of this study is modeled after a distribution center in Taiwan. One unique characteristic of this environment is that its picking area has been divided into different zones. Furthermore, pickers cannot enter a zone if it is occupied by another picker. In this zone-picking environment, the routing strategy it adopts is crucial to its order-picking performance. In this study, we developed nine routing strategies and conducted simulation experiments to understand their performance in three performance measures — total system time, total travel distance of pickers and total busy time of pickers. It is hoped that the knowledge learned from this study can be beneficial to distribution centers with similar zone-picking environments in finding right routing strategies for their zone-picking operations.

2 - The effects of different combinations of routing-strategy traits and I/O-point traits on the order-picking performance of a zone-picking warehouse
Chih-Feng Chou, Ying-Chin Ho

The environment of this study is a zone-picking warehouse, in which the picking area is divided into different zones. In this study, we investigate how different combinations of routing-strategy traits and I/O-point traits can affect the order-picking performance of a zone-picking warehouse. The routing-strategy traits and I/O-point traits considered here are collected from a distribution warehouse in Taiwan and the relevant literature. The routing-strategy traits include: 1) whether the routing-strategy is a fixed-route strategy or a dynamic-route strategy; 2) whether the routing-strategy is an in-sequence-route strategy or a non-in-sequence-route strategy, if it is a fixed-route strategy; and 3) whether overtaking is allowed between pickers, if the routing-strategy is a fixed-and-in-sequence-route strategy. The trait of an I/O (In/Out) point is whether the I/O point is a single-function point or a dual-function point. A single-function point is either an I-point or an O-point, but cannot be both; while a dual-function point can be both an I-point and an O-point. Simulations were conducted to understand the effects of different combinations of routing-strategy traits and I/O-point traits on the order-picking performance of a zone-picking warehouse. It is hoped that the findings of this study can assist distribution centers with similar zone-picking environments in improving their zone-picking operations.

■ WC-50

Wednesday, 12:30-14:00 - Graham Hills GH512, Level 5

Port Logistics

Stream: Maritime Transportation
Invited session
Chair: *Guoqing Wang*

1 - Reliable Planning of Seaport Container Terminal Operations with Capacity Disruptions
Serhan Kotiloglu, Panagiotis Repoussis, Jeffrey V. Nickerson, Gregory Prastacos

Shipment of containerized cargos is crucial for global economy, whereas they are also very vulnerable to disruptions. The readiness of the components of containerized maritime transportation to disruptions, specifically seaport container terminals, is a very important topic that has been under-researched in literature. This work presents a scenario-based mixed integer mathematical programing formulation for the integrated tactical planning of berth allocation and quay crane assignment and scheduling. The goal of the model is to provide optimal utilization of the existing capacity assuming normal operating conditions, and to increase the readiness of the system for (partial) capacity disruptions. The objective is to minimize the berthing time of the ships, while also reducing the disruptions risk using the p-robustness criterion. The disruptions under consideration include decreased berthing areas and/or quay crane disruptions, which would diminish the capacity. The tradeoff between capacity utilization and the reliability of the schedule is demonstrated, proving that significant increases in readiness can be obtained with a minimal change in overall capacity utilization. Both metaheuristic and exact algorithms have been developed for the problem, and various computational experiments are reported that assess their effectiveness.

2 - Scheduling Vessel Unloading at a Bulk Terminal with Tidal Mooring Restrictions
Guoqing Wang

We consider a vessel unloading scheduling problem at a bulk terminal with tidal mooring restrictions. Due to the physical restriction of the terminal, an incoming vessel can only mooring a berth within a series time windows according to the tidal conditions. The objective is to schedule a given set of vessels to minimize duration of the unloading operations. We show the problem is NP-hard in strong sense and develop several heuristics to tackle the problem.

■ WC-51

Wednesday, 12:30-14:00 - Graham Hills GH542, Level 5

MAI: Who do you think you are? Exploring experiences and development of professional identity

Stream: Making An Impact 2 (MAI 2)
Invited session
Chair: *Frances O'Brien*

1 - Who do you think you are? Exploring experiences and development of professional identity
Frances O'Brien

Who do you think you are? When you talk to other people about what you do, how do you describe your role? Do you see yourself as a professional with a strong sense of professional identity? Is your sense of identity is linked to the type of work you do and the experiences you've had throughout your life? If you haven't thought about it much, Frances O'Brien's workshop will give you a great opportunity to explore what influences who you think you are. If you have a strong sense of identity, this workshop would be a great chance to share your story with others. The workshop will be a practical session with opportunities to reflect on your career choices, the type of work you have undertaken and how this has influenced your perception of who you are professionally. Frances will lead a mixture of creative exercises to help you map out the path of experiences that influence your identity as well as opportunities to discuss and share your experiences with others, some of whom may have had quite different experiences to you or be at different stages in their careers.

■ WC-52

Wednesday, 12:30-14:00 - Graham Hills GH554, Level 5

CTRM: Commodity Trading & Risk Management

Stream: Financial and Commodities Modeling
Invited session
Chair: *David Stack*
Chair: *Rosella Castellano*

1 - CTRM software adapted from commercial version to teach academically - founded on first principle commercial reality.
David Stack, Sorin Hilgen, Wincenty (Vince) Kaminski

A Commodity Trading and Risk Management system to teach in academia is presented. With an OR core the system is used to teach how trading companies, utilities and banks manage derivatives by greek. An integrated front-middle-back office deal booking and risk management approach is considered. Regulatory compliance and normal MCLO (market, credit, legal, operational) risks are addressed. Portfolio construction and T+1 analysis is presented and discussed. As a critical review TDelta, $Vega, $Theta and $Rho are reviewed across practitioner publications and academic articles. VaR is discussed as an "invalid" risk measure, commercially. The "rule of three" for VaR as a risk measure is reviewed. ASEAN energy markets teaching is discussed in the context of PRA's (price reporting agencies) presence and little organised exchange activity. The role of Chinese futures markets, now the worlds largest, is discussed. The comparison of teaching methodology and learning outcomes needs is used to contrast and compare those of practitioners and academics. A PPP which involves regulators and designed to enhance market information sharing is presented.

2 - CTRM: A Trader, Physical broker and Futures brokers analysis of applied research methodolgy
Alastair Dickie

A comprehensive review of OR and research methodology in three critical dimensions is presented. The needs based research methodology of traders and physical and financial brokers and their clients is presented. The outcomes of this research is discussed and reviewed in the context of state and institutional research as well as that of actually generating "commercial edge" and putting your investor or client money at risk. Client advocacy is discussed. Basis Trading analysis methodology, Drawing Arc Theory and a comparion of trading markets which do, and do not, have a futures underlying is presented. Contrast of UK futures with US and other markets is assessed. Existing research of trading houses, banks and brokers is discussed. The comparison of teaching methodology and learning outcomes needs is used to contrast and compare those of practitioners and academics. A detailed propsal for a meaningful PPP is presented, at the Euro level.

3 - Optimal Fuel Mix for Power Generation
Rosella Castellano, Roy Cerqueti, Gianluca Fusai

In this paper we focus on electricity production costs in order to identify the best policy for some European countries as regards the fuel mix for power generation. In other words, for each country under consideration, we propose to determine the optimal fuel mix — within a context of very high price volatility — which would provide the lowest generation cost. The techniques used to model and address this issues are based on dynamic programming, in the context of stochastic control theory.

■ WC-53

Wednesday, 12:30-14:00 - Graham Hills GH614, Level 6

Dynamical Models in Sustainable Development II

Stream: Dynamical Models in Sustainable Development
Invited session
Chair: *Miles Weaver*

1 - Modelling and Simulation for Sustainable Development: A Shift from Normal to Post-Normal Modelling and Simulation Paradigms

Masoud Fakhimi, Navonil Mustafee, Lampros Stergioulas

Sustainable Development (SD) continues to gain prominence within organisations. It is arguable that dealing with challenges posed by SD results in solutions that are becoming increasing complex and are resulting in higher costs. Computer modelling and simulation (M&S) can provide the stakeholders with a decision support tool to analyse the trade-offs associated with the implementation of SD solutions. A review of literature has shown that although sustainability is generally considered to be among the forefront of research in various management streams, the application of M&S for implementing and managing the Triple Bottom Line (TBL) of sustainability are in their infancy. According to our findings, the most important factor for low adoption of M&S for SD results because of the latters' constantly evolving dynamical process where the optimum point is not known in advance and is continually moving; compared to this the former rely on concepts emerging from equilibria and optimality, and are therefore less likely to be useful when observing sustainable systems which necessarily includes plenty of immeasurable social and environmental which do not obey mechanistic laws. The aim of this research is therefore to investigate the challenges in developing models for sustainability analysis and to argue for a shift from normal to post-normal M&S paradigms for sustainability analysis; this is achieved through a discussion on normal and post normal science concepts and assumptions.

2 - A Systems Thinking Approach to Connecting and Aligning CSR Responses to Social Need in Scotland

Miles Weaver, Steven Paxton, Hock Tan, Kenny Crossan, Anne-Marie Reilly

The session aims to present a conceptual model of the governance issues in connecting and aligning the CSR activities of Scottish Businesses and the real and emerging needs in Scotland and the third sector. This forms part of a KTP funded project to design and establish a grant-making platform for the Voluntary Action Fund that encourages the engagement in volunteering and social action in a Scottish context.

The session explores how a 'systems thinking' approach may provide an interesting avenue to explore governance issues to embed sustainability in organisations and across supply chains. Particularly, sustainability-responses that focus on transparent and stakeholder engagement.

Little research has been made in the area of supply chain governance, although research has been made in the area of 'governance and the theory of the firm' and contributions by Carter (2008) and Ashby et al., (2012) on the triple-bottom line in a supply chain context. This includes a discussion on the usefulness of 'rich picture' building from a pilot study of representatives from Scottish Businesses and voluntary sector organisations, funded by VAF.

3 - On the Role of Hartwicks Rule in an Economy with Exhaustible Resources

Rudolf Zimka, Anton Dekrét

In models of economies with exhaustible resources the state and price forms of Hartwick's rule and their generalized versions play an important role at finding conditions for intergenerational equity with respect to constant consumptions or to constant value of a utility consumption function. Economists have been trying to make clear the real position of Hartwick's rules in this domain. The present article contributes to this field. The price forms of Hartwick's rule are investigated with respect to prices satisfying a special model, which is the price (cotangent) prolongation of the DHSS model in the space of price variables. These so called canonical prices enable: a) to find conditions under which the generalized price Hartwick rule is necessary and sufficient to guarantee the intergenerational equity with respect to price equity (the sum of the price evaluation of the consumption functions change rates is zero at each point of time), b) to find conditions for the converse of the price Hartwick rule with respect to price equity. The notion price equity generalizes the requirement for constant consumption over time.

4 - Friedman's Permanent Income Hypothesis under the Slovak Republic Conditions

Kvetoslava Surmanová, Marian Reiff, Michaela Chocholatá, Andrea Furková

This paper presents an econometrics model of consumption expenditures in Slovak republic with the aim to describe consumer behavior before and after the global financial and economic crisis. The consumption plays important part of the total production output and thus is viewed as a source of economic growth. Based on data, previous stable positive development of the main indicators was substituted by slump in period of economic decline. Uncertainty conditions led to build up reserves (savings) for emergencies as it is described in models. The study is based on Friedmans permanent income hypothesis. The impact of the crisis on consumer spending is analyzed based on Friedmans theory modification. This research is based on quarterly data covering the period from 1995 to 2014 and dynamic model is used in hypotheses testing, specifically model with adaptive expectations.

■ WC-54

Wednesday, 12:30-14:00 - Graham Hills GH617, Level 6

Financial Modelling and Portfolio Optimization

Stream: Decision Making Modeling and Risk Assessment in the Financial Sector
Invited session
Chair: *Vladimir Korotkov*

1 - Portfolio Selection Models with Proportional Transaction Costs and Initial Holdings

Marius Radulescu, Constanta Zoie Radulescu

We extend the classical mean-variance model due to Markowitz in order to include transaction costs and initial holdings for the investor. Our approach is new. Our aim is to obtain an optimal portfolio which has a minimum risk or a maximum return. Our portfolio selection models include complementarity constraints since the investor cannot buy and sell at the same time the same asset. This type of constraints increases the difficulty of the problems, which now enter in the category of combinatorial optimization problems. The set of feasible solutions for the problems from the above mentioned class is the union of a set of convex sets but it is no longer convex. We show that the portfolio selection model with transaction costs may be written as a mixed integer programming model with binary variables. We give an heuristic algorithm for finding solutions of portfolio selection models with complementarity constraints. Several numerical results are discussed.

2 - Robust Portfolio Optimisation for Medium Frequency Trading Strategies and Heavy-Tailed Returns

Gonçalo Simões, Raphael Hauser

Although classical mean-variance portfolio optimisation assumes exponentially decaying tails, most asset classes actually exhibit heavy tailed returns, and hence frequency estimates of large scale losses based on first and second moments are inadequate. By classifying returns as either "normal' or "extreme' via a filter, we combine extreme value theory, principal component analysis and convex relaxation in a novel way to arrive at time-poor man's version of a CVAR constraint. This can be cast in second-order programming form and hence the resulting model has the same complexity as a standard mean-variance model. Alternatively, we use this CVAR-like constraint to design an uncertainty set to be used in a robust optimisation framework. In particular we investigate its use on a relative robust optimisation model which has a tractable inner approximation.

3 - On Stability Function of One Pareto Optimal Portfolio of Investment Projects in Multicriteria Boolean Problem

Vladimir Korotkov, Yury Nikulin

In the presentation we consider a multicriteria Boolean problem of the project portfolio selection. The problem is viewed as a problem of finding the set of Pareto optimal portfolios. A portfolio of the investment projects is a Pareto optimal, when its total level of risk, i.e. the sum of risks of the projects included in the portfolio, is minimal in the worst market state for one type of the risk. The initial data of the problem might contain some uncertainties, unpredictable changes, or a lack of information. Some situations may take place when even small deviations in the initial data can involve principal changes in the set of Pareto optimal portfolios. In view of that, the selection of the portfolios for such problem without stability analysis can be senselessly in practice. We present the stability function of a Pareto optimal portfolio.

This concept provides information about the quality of this portfolio in response to changes in the initial data when the portfolio loses its Pareto optimality.

4 - High Frequency Asymptotics for the Limit Order Book

Peter Lakner, Joshua Reed, Florian Simatos

We study the one-sided limit order book for sell (or buy) orders and model it as a measure-valued process. Limit sell (or buy) orders are offers to sell (or buy) an equity at a price determined by the seller (or buyer). Market buy (or sell) orders are orders to buy (or sell) an equity at the best, that is, least expensive (most expensive, in case of sell market orders) price offered by previous limit sell (or buy) orders. Limit orders arrive to the book according to a Poisson process and are placed on the book according to a distribution which varies depending on the current best price. Market orders to buy (or sell) periodically arrive to the book according to a second, independent Poisson process and remove from the book the order corresponding to the current best price. We consider the above described order book in a high frequency regime in which the rate of incoming limit and market orders is large and traders place their limit sell orders close to the current best price. We provide weak limits for the price process and the properly scaled measure-valued order book process in the high frequency regime. The limiting price process turns out to be a reflected Brownian motion.

■ WC-55

Wednesday, 12:30-14:00 - Graham Hills GH626, Level 6

Simulation in Management Accounting and Management Control I

Stream: Simulation in Management Accounting and Management Control
Invited session
Chair: *Alexander Brauneis*

1 - The Effect of Company Size, Beta Coefficient and Dividend Policy on Stock Returns

Mervan Aksu

There are numerous works in the finance literature which emphasize on expected returns and risks for future investments. Those works are based on the idea of the researcher that the factors that he is using would determine the relation between expected return and risk. In this paper we chose stocks as an investment tool. Also, we preferred beta coefficient, dividend policy and firm size as factors which may affect our investment. To describe the effect of those factors on our investment, we chose stocks which were performing in the Istanbul stock exchange industrial index between January 2000 and September 2013. We then calculated the return of those stocks within January 2002 - June 2013. In order to show the effect of those factors we built seven main portfolios. These portfolios are based on the firms that we selected for our research purpose. We divided those firms according to each factor: for beta coefficient we divided those firms into two portfolios; we divided those firms into two groups according to their dividend policy; lastly we divided those firms into three portfolios in accordance with their size . In our research we also tried to show the effect of dual combination of the factors that we have chosen. In order to show the effect of dual combination of those factors we created 16 sub portfolios. We monthly calculated the return of those portfolios and we also yearly reconstructed them according to each factor. we also used risk adjusted performance measurements

2 - Knowledge Creation Strategy, Intrafirm Collaboration Networks and Innovation

Sui-Hua Yu

Inside an organization, inventors can learn from each other through collaboration. However, individuals are cognitively bounded, and their technological knowledge is highly specialized. The pattern through which a firm's inventors exchange their knowledge may influence the innovation outputs. Therefore, this paper conceptualizes an organization as a network of interpersonal links and investigate a firm's capability to innovate by analyzing the structure of its internal collaboration network. Based on the empirical results, we find evidence that the extent to which inventors span structural holes in the network is associated with higher innovation outputs. Furthermore, we find firms with greater reliance on familiar knowledge or on diverse knowledge have a significantly greater innovation return to their spanning of structural holes in the networks. Our findings indicate that a firm with reliance on diverse knowledge base is more capable of developing innovative outputs in the presence of internal knowledge sharing; a firm with reliance on its proprietary knowledge is better able to achieve superior innovation through internal collaboration. These results suggest the importance of fit between a firm's knowledge creation strategy and its internal network structure.

3 - An analytic solution to Vickrey auction style investment decisions

Alexander Brauneis, Stephan Leitner

We model a firm which offers funding for one investment project in a Vickrey-style auction. Out of N noisy proposals the highest net present value (NPV) project is actually put into action, whereby the winning proponent is paid a fixed compensation of the difference of the best and the second best project. Since capital budgeting decisions necessarily rely on forecasts of cash flows, noisy forecasts of future project cash flows imply erroneous project NPVs and, as a result, faulty compensation payments. The inverse gamma distribution and order statistics thereof are used to derive a closed form approximation for the expected NPV of the winning project, when the selection decision is based on one estimate of cash flows for each project under consideration. Consequently, we compare theoretical results to those of simulated data.

■ WC-60

Wednesday, 12:30-14:00 - Graham Hills GH813, Level 8

Relief Distribution and Investments

Stream: Disaster Risk Management
Invited session
Chair: *Maria Paola Scaparra*

1 - Clustering strategies to aim a disaster relief delivery; efficient and resilient

Jorge Vargas, Rafael Alva

Transport costs represent between one tier to two tiers of total logistics cost (Ronald Ballou, Logistics: Supply Chain Management, 2004). On the other hand, funds to face humanitarian operations have been multiplied ten times over the last decade, for instance in 2013 international appeal totalled US\$ 22,0 billion, that was 27,2 % more than one requested in 2012 (according to the Global Humanitarian Assistance Report 2014). All these facts have pushed humanitarian organizations to become more result-oriented. A frequent problem in a disaster relief is reducing the transport cost keeping an acceptable distribution service. The latter depends on a reliable delivery route design, which is not evident considering a post disaster environment, where infrastructures and sources could be inexistent, not available or not operative. Therefore the odds that the disaster relief can arrive at impacted areas to population decrease. This paper tackles this problem, taking in count those constraints to deliver in a post disaster environments as an 8 M earthquake on the Peruvian Capital city. The present research compares different clustering strategies to design a relief delivery; efficient and resilient. Routes' analysis found that by the Ascending Classification Hierarchical (HAC), solved by Linear Programming, has achieved the best result.

2 - Relief distribution network design in the context of natural disasters in Chile

Pamela P. Alvarez, Andres Bronfman, German Paredes-Belmar, Armin Lüer-Villagra

After a disaster strikes, the delivery of relief items to the affected population is crucial and it is necessary do it efficiently due the existence of uncertainty (from different type) and the scarcity of resources. To reduce the suffering of the population is important to give to the affected people the relief supplies that they need in the shortest time possible. This research tries to contribute in this challenge. Specifically, this work presents a methodology to relief distribution network design in a strategic and tactical level. The network design includes the localization of humanitarian aid centers in the relief supply chain, the assignment of the population's requirements to these centers and the vehicles that carry the relief items to the affected population. The methodology consists in a mixed integer programming problem that minimizes

a response time and determines the delivery time the supplies for every affected population. This is our main contribution. The model is, indeed, a good tool to support strategic and tactical decision-making in scenarios post disaster. The proposed methodology is applied to relief supplies distribution in a specific zone in the VIII Region of Chile.

3 - Optimizing railway system security investments to mitigate disaster effects
Maria Paola Scaparra, Stefano Starita

Past and recent events have shown that railway infrastructure systems are highly vulnerable to natural catastrophes, unintentional accidents and terrorist attacks. Protection investments are instrumental in reducing economic losses and preserving public safety. A systematic approach to plan security investments is paramount to guarantee that limited protection resources are utilized in the most efficient manner. This talk introduces an optimization model to identify the railway assets which should be hardened or protected to minimize the impact of worst case disruptions on system performance. We consider dynamic investments over a planning horizon. The problem is formulated as a bilevel mixed-integer model and solved using two different decomposition approaches. To demonstrate how the approach can be used to support efficient protection investment decisions for real railway infrastructure, a case study on the Kent (UK) railway network will be presented.

■ WC-61
Wednesday, 12:30-14:00 - Graham Hills GH816, Level 8

Routing Applications - Flight

Stream: Routing II - Emerging Applications
Invited session
Chair: *Wolfgang Garn*

1 - A Real-Life Dial-A-Flight Problem
Ian Campbell

A real-life airline taxi problem, or Dial-A-Flight problem, is described. The airline ferries tourists and operates in a safari region in Northern Botswana. Various characteristics of the problem are discussed and the problem is compared to other vehicle routing problems. An exact solution method and a method using "composite variables" are applied and the results compared. The method using composite variables was found to be a practical and useful method for generating good schedules.

2 - Resource and time dependent flight altitude routing
Anders Nicolai Knudsen

Flight routes are calculated on a network of waypoints representing 3D-coordinates. The cost of flying through a path in the network is determined by fuel consumption and time duration, which are influenced by the aircraft performance and the weather conditions. However, these latter two are in turn related to the fuel and time. The goal is to find a feasible route that minimizes the cost. Due to the complexity of the problem, it is most commonly addressed in two steps: first, a route in a 2D-network is determined; successively, the altitude of the flight is optimized. Deciding the altitude at each waypoint of a 2D route, such that the cost is minimized, is itself a challenging problem due to the presence of complex dependencies in the cost calculation. Weather conditions change with time and make an arc more or less appealing from a fuel cost perspective depending on when it is traversed. This dependency invalidates the FIFO-assumption, which is common for time-dependent networks. Moreover, the weight of the aircraft, that influences the performance, depends on the amount of fuel embarked at departure, but this amount is known only when a 3D route is found. We design a labelling algorithm that uses a lower bound procedure, instead of the FIFO-assumption, to dominate and select partial routes. We cope with the unknown initial amount of fuel by iterating the search phase, starting from a feasible estimate, and refining the amount based on the route found at each iteration.

3 - Drones reveal efficiency savings in delivery services
Wolfgang Garn

Drone delivery services (DDS) are an upcoming reality. Companies such as Amazon, DHL and Google are investing in developments in this area. German's parcel delivery company DHL has started applying them commercially. This emphasises the importance to have insights in the economic benefits of drone delivery services. This study compares drone delivery services with traditional delivery services. The cost effectiveness of integrating drones into a delivery services' operations is analyzed. The study identifies and categorise several factors that control the delivery operations. A mathematical model comparing 3D flight paths of a fleet of drones with a fleet of 2D van routes is developed. The proposed formulation can be seen as an extension of the Vehicle Routing Problem (VRP). Efficiency savings given by drone services of real world rural postcode sectors are analyzed. The present study is limited to the use of small unmanned aerial vehicles (UAVs) with a low payload, which are GPS controlled and autonomous. The case study shows time, distance and cost savings when using drones rather than delivery vans. The model reveals efficiency factors to operate DDS. The study shows the economic necessity for delivering low weight goods via DDS. The primary methodological novelty of this study is a given by model that integrates factors relevant to drones into the VRP.

■ WC-66
Wednesday, 12:30-14:00 - Livingstone LT209, Level 2

Logistic

Stream: Optimization
Invited session
Chair: *Enrique Benavent*

1 - A new model to optimise sustainability in a supply chain design
Hamid Allaoui

The main objective of this paper is to propose new model to jointly optimizing financial, environmental and social cost of an agri-food supply chain design: Triple Bottom Line. We aim to overcome the lack of integrated optimization methods across the different decision levels on managing such logistic systems. This model will constitute the core of a decisional framework structured architecture to help food companies been sustainable innovative and competitive. Indeed, several food supply chains become quite well equipped in terms of information systems and administrative management. However, to make adequate decisions optimizing the 3BL, decision support systems connected to the management should be envisaged. The main objective is to make global strategic optimizations in the supply chain network. We shall consider in the proposed model joint optimization of financial, environmental and social cost of an agri-food supply chain design. This model involves the formulation of an MILP with multiple three objective functions. We optimise the total cost of supply chain. For the environmental aspect, we optimize the carbon footprint and water footprint, since they have the largest impact on environment. For the social aspect, we optimise the number of created jobs. At last, we generate a Pareto front to aid the user's decision making. This work were supported by the European program INTERREG IVB via the project "Step Change Agri-food Logistics Ecosystems: SCALE'.

2 - A tri-level mathematical model for real time control of electrical distribution network
Sonia Toubaline, Pierre-Louis Poirion, Claudia D'Ambrosio, Leo Liberti

Several electrical measurement devices are designed, developed and deployed within the SoGRID project in order to monitor and control a medium voltage electrical network in real time. We are interested in the optimal placement problem of these devices such that the total measurement cost is minimized and the convergence of the state estimation function is ensured. We present a tri-level model for this problem and discuss some solution methods and preliminary computational results.

3 - The logical dominance method (LDM): application on the MO-TSP
Jacques Teghem, Samya Elaoud, Taicir Loukil

We propose a new exact method, noted LDM for permutation Moco problem based on dominance rules. The method uses the particular

structure of the considered problem in order to eliminate some dominated decision space régions. The LDM proposes many rules that when combined together along with an iterative solving Branch and Bound, makes an efficient reolution tool. It is illustrated on the bi-objective travelling salesman problem.

4 - The Probabilistic Pickup and Delivery Traveling Salesman Problem
Enrique Benavent, Mercedes Landete, Juan José Salazar González, Gregorio Tirado

The Pickup and Delivery Traveling Salesman Problem is a routing problem in which one vehicle have to satisfy a set of customer orders where each order involves the transportation of an item from a given origin to a given destination. In the Probabilistic Pickup and Delivery Problem (PPDTSP), for each order there is a given probability that the customer withdraws it at the time the route is performed. This means that a route has to be designed for all the orders, but in the realization of the route the visits to the points corresponding to the removed orders will be skipped. The objective is to design the route with the minimum expected length. In this work we address the case where all the orders are independent and have the same probability of being removed. We propose two integer linear formulations of the problem. The first formulation is a compact one, that is, the number of variables and constraints is polynomial in the number of requests, while the second one contains an exponential number of constraints and is used as the basis of a branch- and-cut algorithm. The performance of the proposed solution methods is evaluated through an extensive computational study using instances of different types that were created by adapting existing benchmark instances.

■ WC-67
Wednesday, 12:30-14:00 - Livingstone LT210, Level 2

Graph Searching

Stream: Graph Searching
Invited session
Chair: *Nancy Clarke*

1 - Brushing without capacity restrictions
David Pike

We consider a variant of the problem of cleaning a graph with brushes, whereby one vertex is cleaned at a time and there is no restriction on the number of brushes that are permitted to traverse an uncleaned edge. Given a graph, the main question of interest is to determine its brushing number, which is the minimum number of brushes that enable the graph to be cleaned. We obtain results for trees and Cartesian products, as well as general upper and lower bounds on the brushing number. This is joint work with Darryn Bryant, Nevena Francetic, Przemyslaw Gordinowicz and Pawel Pralat.

2 - How many cats does it take to catch a mouse?
Bill Kinnersley

We discuss the cat and mouse game on graphs, a recently-introduced pursuit-evasion model. In this game, a team of cats attempts to capture a mouse who resides on some graph G. The mouse occupies a vertex of G and, in each round of the game, may either remain in place or traverse a single edge. The cats iteratively attack vertices of G, winning if any cat ever attacks the mouse's vertex. The cats are free to attack any vertices they please, without regard to the structure of G. However, they have no knowledge of the mouse's position: he is invisible.

Given a graph G, it is natural to ask how many cats it takes to catch a mouse on G; the minimum number of cats needed is the cat number of G. In this talk, we give some bounds on the cat number in terms of other parameters of the host graph. We also establish connections to other pursuit-evasion games. We conclude with several intriguing open questions.

3 - The expanding search ratio of a graph
Thomas Lidbetter

Suppose a stationary Hider is located at an unknown vertex of a rooted graph with weighted edges. An expanding search of the graph is a sequence of arcs starting at the root, each of which is incident to a vertex already searched. The search ratio, or competitive ratio of an expanding search is defined as the maximum value over all vertices of the ratio of the time taken to reach that vertex and the shortest path to the vertex from the root. The search ratio of a graph is the minimal search ratio of any expanding search and the randomised search ratio is the minimal expected search ratio of any randomised expanding search. Finding the randomised search ratio is equivalent to solving a zero-sum game. We show that for graphs with uniform edge weights and for trees, the optimal deterministic expanding search is the one that searches the vertices in order of their distance from the root. This also gives a 2-approximation for the optimal randomised expanding search. We show that the star network with a given number of edges that has both minimal search ratio and minimal randomised search ratio is the uniform star, and we give a simple algorithm for finding the optimal randomised expanding search of a star under certain conditions. This is joint work with Spyros Angelopoulos.

4 - Variations of the Cops and Robber Game Played with Multiple Robbers
Nancy Clarke

Two variations of the Cops and Robber game are introduced in which the robber side consists of multiple robbers. In the first, there are "gangs' of robbers that can win by attacking a cop. In the second, the robber side uses "decoys' to confuse the cops, allowing the actual robber to escape. We present a variety of results for both models, including recognition theorems for graphs on which a single cop can guarantee a win, as well as strategies that can be used by the cop to win on such graphs.

■ WC-77
Wednesday, 12:30-14:00 - Collins Insight Institute

Behavioural OR: The next 10 years (Discussion Panel)

Stream: Behavioural Operational Research
Invited session
Chair: *L. Alberto Franco*

1 - Behavioural OR panel discussion: A decision analysis perspective
Konstantinos Katsikopoulos

In this panel discussion we offer a range of disciplinary perspectives on the nature of Behavioural OR, assess its current status, and debate possible directions for its development in the next 10 years.

2 - Behavioural OR panel discussion: A group decision and negotiation perspective
Rudolf Vetschera

In this panel discussion we offer a range of disciplinary perspectives on the nature of Behavioural OR, assess its current status, and debate possible directions for its development in the next 10 years.

3 - Behavioural OR panel discussion: A supply chain forecasting perspective
Konstantinos Nikolopoulos

In this panel discussion we offer a range of disciplinary perspectives on the nature of Behavioural OR, assess its current status, and debate possible directions for its development in the next 10 years.

4 - Behavioural OR panel discussion: A cognitive perspective
Etienne Rouwette

In this panel discussion we offer a range of disciplinary perspectives on the nature of Behavioural OR, assess its current status, and debate possible directions for its development in the next 10 years.

5 - Behavioural OR panel discussion: A social science and mathematical modelling perspective
Kai Helge Becker

In this panel discussion we offer a range of disciplinary perspectives on the nature of Behavioural OR, assess its current status, and debate possible directions for its development in the next 10 years.

■ WC-78

Wednesday, 12:30-14:00 - Architecture AR201, Level 2

Societal Complexity and Healthcare

Stream: Methodology of Societal Complexity
Invited session
Chair: *Cor van Dijkum*
Chair: *Dorien DeTombe*

1 - Exact Approaches For Patient Scheduling Within a Private Surgery Department
Hejer Khlif Hachicha, Farah Zeghal Mansour

We study a patient scheduling problem arising in a private surgery department. It aims to optimize the resource utilization of the entire surgery process including pre-operative, per-operative and post-operative activities. The problem consists on scheduling surgery patients during one day period so as to minimize the completion date while considering hospital beds, operating rooms, recovery beds and surgeons preferences constraints. The problem is modeled as a hybrid flowshop scheduling with recirculation, dedicated machines, and simultaneous use of resources. We present two mixed integer linear programs. In the first one, the patients' assignment to resources and sequencing are expressed by a same decision variable whereas, in the second model, different variables are used for these two decisions. Both programs are solved using commercial optimization software CPLEX. Computational experiments are performed on real instances of a Tunisian private clinic: Clinique Ennasr and on randomly generated instances to evaluate and compare the effectiveness of the two proposed programs.

2 - Operations Research in Higher Education Complex Systems
Zilla Sinuany-Stern, Lea Friedman

We advocate the importance of using Operations Research (OR) methodologies in Higher Education (HE) for enhancing HE complex systems. Areas in HE where OR can be used include: facility planning and scheduling, faculty outputs and compensation, budgeting, quality assurance, international comparisons, ranking universities, students choice of institution, students admission. OR methodologies used for HE are: optimization models, scheduling, forecasting, simulation, Data Envelopment Analysis, game theory, multi-criteria decision analysis, etc. We will present a specific example of measuring the differentiability of faculty salaries in Israeli universities by rank, by institution, and by faculty outputs.

■ WC-79

Wednesday, 12:30-14:00 - Architecture AR310, Level 3

Sports Economics

Stream: OR in Sports
Invited session
Chair: *Giambattista Rossi*

1 - Capturing preferences of Belgian football fans: evidence from a discrete choice experiment.
Dries Goossens, Martina Vandebroek, Chang Wang

In the past decade, a considerable amount of money was invested by television broadcasters to acquire the Belgian Pro League broadcasting rights. While broadcasters pursue a maximal audience rating, clubs try to have full stands for each home match. Both find themselves impacted by the fixtures, which determine which opponents will face each other in which part of the season, and at what kickoff time. Our contribution aims to capture the Belgian football fans' preferences with respect to various scheduling options, some of which have not been used before. We carried out a discrete choice experiment using an online survey questionnaire distributed on a national scale, including questions on TV viewership as well as on stadium attendance. The choice sets are based on three match characteristics: month, kickoff time, and quality of the opponent. In each part, a semi-Bayesian D-optimal design for the conditional logit model was used to generate the choice sets. The choice data is analyzed using a conditional logit model (assuming homogenous preferences) as well as with a mixed logit model. The models predict the utility of watching a Belgian Pro League match — either on TV or in the stadium — for every possible scheduling option. We validate the predicted utilities against real audience rating and home attendance data. Finally, we discuss how our results can be used to improve the scheduling process of the Belgian Pro League.

2 - Economic Impact of Organizing Large-Scale Sports Events
Elmer Sterken

We analyse the impact of organizing large-scale sporting events on real per capita GDP of organizing countries. We include the Summer Olympic and Winter Olympic Games and the FIFA World Cup Soccer events, being multi-day nations-wide tournaments, across the sample period 1896-2012.

First we present descriptive statistics that illustrate that especially the Summer Olympic Games organization is correlated with relatively large real per capita GDP growth rates. Next we show that this positive correlation might be due to a selection effect. We model the decision to be a candidate organizer and final host and show that countries that have stronger economic momentum are more likely to candidate and host the event.

This finding contrasts cost-benefit analysis of impact of mega sports events, which typically have a more regional or sectoral scope. For smaller countries the expected returns of organising large-scale sports events is larger than for larger countries, but higher yields come with higher expected risks. We model this risk in terms of unconditional expected variances of real per capita output.

3 - Using two Data Envelopment Analysis models to assess the efficiency of sports and propose financial resources reallocation
Lidia Angulo-Meza, Renato Valério

In this paper we use DEA to evaluate the efficiency of its Olympic sports and, based on the outcome, to reallocate the financial resources received by each one. Financial resources from the Agnelo/Piva Law were used. Two different models, varying in the usage of variables, were proposed. In both models the number of gold medals offered by each sport was considered as input, as a proxy for difficulty measure in winning a medal, and also the number of gold, silver and bronze medals won by each sport were considered as outputs. The main difference between these two models is the choice of the input related to financial resources. The first model uses as input the funds coming from the Agnelo/Piva Law in order to evaluate the application of such funds. The second model uses as input a ratio of those funds to the monthly cost of the Olympic team, taking into account the maintenance and development cost of each sport while evaluating the application of the funds. In both cases a DEA non-radial model with weights restrictions was formulated to determine the efficiency of the sports and also to determine benchmarks for all the inefficient ones. Afterwards, a DEA-ZSG non-radial model with weights restrictions was used to determine the reallocation of resources. Reallocation results were compared with the resources distribution made previously by the Brazilian Olympic Committee. The use of DEA proved to be very suitable for the application in sports proposed.

4 - Production, Efficiency and Corruption in Italian Serie A Football: A DEA Analysis
Giambattista Rossi, Gian Luca Di Tanna, Francesco Addesa

This paper uses data for Italian Serie A football to analyse the relative efficiency of the clubs playing in it. While there has been considerable research on production and efficiency in Spain's La Liga and the English Premier League, corresponding evidence relating to Serie A is limited. This paper addresses this imbalance utilising a panel dataset comprising season aggregated match statistics for 36 clubs that played in Serie A over ten seasons from 2000/01 to 2009/10 inclusive. The seasons covered by the data include those affected by the Calciopoli corruption scandal and we incorporate indicators for these events in

the statistical model. To achieve this, we have used mathematical optimisation methods, particularly DEA models, which enable the calculation of the frontiers if efficient production. We also analyzed the associations between efficiencies and season effects by OLS models and, and to take account of the variability between team we performed random-effects models. Some of the most interesting results are the following. Firstly, the results highlight the importance of attacking play in Serie A. In contrast to the literature, the popular maxim in Italy that the best attack begins with a good defence does not hold. Secondly, clubs involved in the Calciopoli scandal with point-deductions were more defensive efficient than the other clubs.

■ WC-80

Wednesday, 12:30-14:00 - Architecture AR311, Level 3

Economic Modelling and Supply Chain Management

Stream: Mathematical Economics
Invited session
Chair: *Marco Dall'Aglio*

1 - Maxmin Equitable Allocation of Homogeneous Goods: The Three Player Case.
Marco Dall'Aglio, Camilla Di Luca, Lucia Milone

We present an algorithm returning a maxmin equitable allocation of a finite number of homogeneous divisible items among three players with idiosyncratic preferences. The algorithm considers two important structures from fair division theory: the Partition Range (defined in L.Dubins and E.Spanier, How to cut a cake fairly, American Mathematical Monthly 68 (1961) pp.1—17) and the Radon-Nikodym Set (defined in D.Weller, Fair division of a measurable space, Journal of Mathematical Economics, 14 (1985), pp. 5-17). We characterize those tools for the setting we consider, and, in turn, we characterize any optimal allocation, giving a bound for the number of split object. We then transform the problem into that of minimizing a function on a graph and we show that the minimization requires a finite number of steps. Finally, we define a procedure to obtain the optimal allocation from the minimizing solution of the graph.

2 - Efficient Computation of Shapley Value for Large Linear Production Games
Phuoc Le, Tri-Dung Nguyen, Tolga Bektas

In Linear Production Games, allocating the total profit of a production enterprise among the resource owners is one key research question. Shapley value provides a popular solution concept and a mathematical framework for determining a fair way of sharing the cooperation benefit. However, finding its exact value for large Linear Production Games (with the number of players greater than 30) is challenging. This paper proposes to use Linear Program sensitivity analysis and stratified sampling techniques to estimate Shapley values for these large problems. We also develop two randomized algorithms based on proposed methods and present their computational results.

3 - Recognizing Single-Peaked Preferences on Aggregated Choice Data
Bart Smeulders

Single-Peaked preferences play an important role in the social choice literature. In this paper, we provide necessary and sufficient conditions for observed behaviour to be consistent with a mixture model of single-peaked preferences for a given ordering of the alternatives. These conditions can be tested in time polynomial in the number of choice alternatives. In addition, algorithms are provided which identify the underlying ordering of choice alternatives if ordering is unknown. These algorithms also run in polynomial time, providing an efficient test for the mixture model of single-peaked preferences.

4 - Supply Chain Coordination with Node Communication and Information Asymmetries
Dimitris Zissis, George Ioannou, Apostolos Burnetas

We consider a supply chain with two nodes, one supplier and one buyer which interact, in a decentralized manner. The supplier produces a single product in a lot-for-lot fashion; thus, completed lots are directly forwarded to the buyer. The latter has to decide on the order quantity (lot size) and he can hold inventory to satisfy market demand (shortages or backorders are not allowed). The nodes are forced to interact with each other and no alternative for external interaction is allowed. Both nodes are rational, risk neutral, have set-up costs and possess private information that affects their reservation levels. We capture information asymmetry assuming that the supplier's production cost and the buyer's holding cost are both discrete random variables. The business relationship can be modeled via a Bayesian game. The retail price and the market demand are constant, exogenously defined and known to the nodes. Our goal is to examine how coordination of the nodes decisions can be reached so that the individual gains of each node are (at least) slightly increased. To reach coordination we allow the nodes to communicate concerning any private information they may possess, and the supplier to provide the retailer with an appropriate quantity discount, in order to induce him to order the joint optimal quantity. We prove that coordination is feasible via quantity discounts and node communication, and devise exact expressions for the optimal nodes' strategies.

5 - Subsidy Scheme or Price Discount Scheme? Mass Adoption of Electric Vehicles Under Different Market Structures
Lulu Shao, Jun Yang, Min Zhang

This article analyzes an electric-and-gasoline vehicle supply chain in different market structures: monopoly setting and duopoly setting. Taking social welfare into account, government offers subsidy incentive scheme or price-discount incentive scheme to electric vehicles (EVs) buyers to promote the adoption of EVs. In this paper, we formulate a utility model composing of a population of consumers who make utility-maximizing choices and manufacturers who make optimal pricing that responds to the interventions of government. Using this model, a framework for policy makers to find optimal subsidies or optimal price discount rates is developed. Different from the monotonicity relationship in monopoly setting, the relationship between consumer low carbon awareness and the EVs' demand depend on government's policy. Although the demand of EVs, consumer surplus, environment impacts and social welfare are identical under two incentive schemes, government prefers to implement subsidy incentive scheme due to lower expense. Furthermore, under subsidy incentive scheme, car market in monopoly setting has less environment impacts but more social welfare compared to the market in duopoly setting.

■ WC-82

Wednesday, 12:30-14:00 - Architecture AR401b, Level 4

Health Care Scheduling

Stream: Scheduling in Healthcare
Invited session
Chair: *Brigitte Werners*

1 - Influence of appointment slots on patient waiting times in primary care
Brigitte Werners, Matthias Schacht, Lara Wiesche

Patient waiting time is a very important criterion for the quality of health care, particularly when waiting for treatment by general practitioners. In primary care two types of appointments exist: urgent or same-day appointments and prescheduled appointments which are booked in advance. How many and where to schedule slots for prescheduled appointments influences direct and indirect waiting times of patients and the utilization of doctors. The challenge is to provide as little as possible prescheduled time slots to see as many same-day patients as possible during regular working hours whilst ensuring comfortable appointments. Deciding on the amount of appointment slots has not yet been focused on in literature. Schedules are regularly influenced by uncertain demands due to amount of acute patients, inter-arrival times and treatment durations. Consequently, the performance of an appointment system depends on various uncertain parameters. Based on an exemplary case study, we show how appointment slots influence different criteria and how to find good compromise solutions. For this purpose we developed a simulation model with dynamic and stochastic data and used it to evaluated the results of different solutions which we determined by our innovative multi-criteria MILP model.

2 - Panel Management in Medical Practices
Anne Zander, Christiane Barz

We consider a general practitioner who has a patient panel consisting of those patients that visit her on a regular basis. We assume that the demand treated by the physician is mainly generated by that panel. The research question is: "How to manage the patient panel in order to achieve a balance between supply and demand now and in the future?' So far, this question has mainly been treated modeling the panel as a set of identical patients. Even if different patient characteristics have been considered (leading to different average consumptions of the physician's time) the problem has only been solved statically for one point in time. We consider the problem dynamically where we take different patient characteristics and their evolution over time into account. We define criteria to measure the value of a given panel based on the current and future time consumption of the panel and present integer linear programs to determine optimal panels, the mix of patients to be integrated to reach an optimal panel, and to decide about admission for a specific patient request to enter the panel. This optimal admission strategy is then compared to other heuristic admission strategies in a simulation experiment.

3 - Assortment and inventory planning for surgical tools in health care sector
Satyaveer Chauhan

In an Operating Theater, many surgical tools are needed to complete a surgery. The combination of tools needed often vary depending upon the nature of the operation/procedure. In general, medical staff prepare a surgical tray containing all the specific tools needed for the operation. Most of the time, surgeons are free to personalize their surgical tray and this individual customization comes at great financial cost. To simplify the customization, hospitals prefer to create a few select customized surgical trays that can be used in any operation. The biggest advantage is that the hospital can order big volume of these trays from suppliers and suppliers can offer competitive prices. Furthermore, inventory planning for few selected trays is much easier than the inventory planning of personalize trays. However, the biggest disadvantage is that a tray may contain surgical tools not required for a designated surgery and thus considered waste. The goal is to balance the cost of customization versus the cost of standardization. In this work we model this as an assortment problem and present a column generation based approach to tackle the customization issue. The model will be tested on the real data, obtain from a local hospital, and the obtain insight will presented.

4 - Scheduling medical specialist appointments in a Chilean public hospital
Carolina Misle, Sergio Maturana

In the Chilean public health system patients who need to see a medical specialist must ask for an appointment in their assigned hospital. Unfortunately, there are several hospitals that have very long waiting lists. The time needed to wait to see a specialist in many cases is excessively long. The hospital needs to schedule appointments for two main types of patients, those that come for the first time to see the specialist and those that need to be controlled. Both can be assumed to arrive randomly over time. Patients also have different priorities, depending on their medical diagnosis. Some need to see the specialist very soon, others can wait longer. Given the long waiting times, it is important to make sure high priority patients are scheduled so they can see the specialist in the required time. However, since is also important to insure fair access to the specialists for all patients, we propose a scheduling system that reserves a portion of the time slots to high priority patients leaving the rest for the regular patients, both new and control. If these slots are not assigned after a certain date, they are available to the other types of patients. The appointment scheduling problem of an important Chilean public hospital was modeled as a Markov Decision Process that minimizes the expected cost of the patients wait for seeing the specialist. Preliminary tests are being carried out to test the feasibility of the system.

Wednesday, 14:30-16:00

■ WD-03
Wednesday, 14:30-16:00 - TIC Auditorium A, Level 2

Keynote Lecture: Ariela Sofer

Stream: Plenary, Keynote and Tutorial Sessions
Keynote session
Chair: *Gerhard-Wilhelm Weber*

1 - OR Education in the Age of Analytics
Ariela Sofer

With the explosion of data in the past few years, many universities have raced to establish new graduate programs in data analytics, or big data. Such programs are often interdisciplinary, drawing from disparate faculty from statistics, computer science, business, and of course, operations research. At the same time traditional masters programs in OR have not (for the most part) rushed to revise their core curriculum in response to the rapid growth in data. It is our contention that every OR graduate going into the workplace today must have a broad comprehension of how large quantities of data can be transformed to information and in turn to informed decisions. How can we change the OR core to accommodate this need while still maintaining an "OR-centric" curriculum? This presentation will examine the challenges and offer some possible approaches.

■ WD-07
Wednesday, 14:30-16:00 - TIC Conference Room 1, Level 3

Applications of OR in Electronic Design

Stream: Engineering Optimization
Invited session
Chair: *Lilia Zaourar*

1 - Efficient Solutions for the Manufacturing of Vias/Contacts Using DSA Technology
Dehia Ait-Ferhat, Yann Kieffer, Gautier Stauffer, Vincent Juliard, J. Andres Torres

An integrated circuit is composed of several electrical components etched over multiple layers. We focus in this study on the manufacturing of a set of vias that connect components from two consecutive layers. One of the basic steps in this process is Lithography. Lithography imposes a certain minimum distance for two vias to be printed simultaneously. Hence dense layouts are decomposed into feasible sub layouts (a.k.a. masks) that will be printed sequentially to produce the original arrangement: this is called Multiple Patterning (MP). Each lithography step is costly and the goal is thus to minimize the number of masks in this decomposition. This problem can be modeled as a graph-coloring problem in unit disk graphs (a NP-hard problem) and a number of good heuristics exist. Directed self-assembly (DSA) is a promising solution to reduce further the number of masks. The idea is to group vias that have to be assigned to different masks in MP to a same mask combining DSA and Lithography. The main challenge of our study is to find the best way of grouping vias (following imposed rules) in order to minimize the number of 'hybrid' masks. This problem somewhat reduces again to a coloring problem in a unit disk graph to which we add additional edges representing constraints which are specific to the DSA process. We will present this formulation and preliminary results that show the potential benefit of DSA over pure MP.

2 - A Tale of Two Models (About Useful Skew)
G.a. Narboni

In synchronous circuits, an excessive skew in the clock signal driving a register can lead to malfunctions. Indeed, the skew should always lie within a range rigorously determined by timing analysis. Now if a zero skew is a solution, a perfect synchronization is not a panacea. The simultaneous switching of all the memory elements is an important source of noise that causes interferences in radio frequency bands.

So some skew can be useful for electro-magnetic compatibility. In this talk, we go back to a solution method especially developed for low-emission circuit design. To the timing constraints we add a shaping constraint which transposes the emission capping requirements to the time domain. This forces a definite spreading of the clock skew distribution. The resulting Constraint Satisfaction Problem can be stated with two global constraints, including a cumulative one. From a theoretical standpoint, it amounts to solving a unit-execution-time scheduling problem, arguably the simplest of all the complex resource-constrained scheduling problems. A more involved transcription can be given as a Integer Programme made up of a tension problem and a network flow one. Separately, both sub-problems are in P, but as shown by Ullman, their conjunction is in NP. From a comparison of these alternative models we come to the conclusion that a 'fully elastic scheduling problem' and a 'global cardinality constraint' refer to exactly the same specialization of the general cumulative idea.

3 - Optimizing Memory Hierarchy in the Embedded Vision Systems
Khadija Hadj Salem, Yann Kieffer

The design of embedded vision systems presents many challenges, including the stakes of energy consumption, performance (real-time aspect), and cost. For video, for example, big images have to be processed by image algorithms (called kernels in the following), and this has to be repeated several times per second - a common repetition number being 25 images per second. But big data and small access times are incompatible with regards to memory banks design. Linear access kernels can use traditional caches to alleviate this problem. For the case of non-linear access kernels, Mancini et al [1] proposed a software system to design ad-hoc memory hierarchies, called MMopt. The final aim of the work presented is to enhance the run-time performance and lower the cost of the design blocks produced by MMopt. Since several optimization criteria are considered, several models for particular sub-problems are presented. Our models are mono-objective optimization problems, with clearly delineated inputs and outputs. Their complexity is established, and they are compared to the closest problems found in the literature. The general case is shown to be NP-hard, while a sub-case is polynomial. We will present the models, complexity analysis, and solution methods for some of the problems encountered in this work. [1] S. Mancini and F. Rousseau. Enhancing non-linear kernels by an optimized memory hierarchy in a high level synthesis flow. DATE, pages 1130—1133. IEEE, 2012.

4 - Shorter Repeater Trees by Optimal Embedding of Steiner Trees with Length Restrictions
Jens Maßberg

An important task in chip design is to build energy-efficient repeater trees. Repeater trees distribute a signal from a source to several sinks on a chip by a tree like elecrical network. Thereby timing constraints have to be satisfied, that is, the signal has to arrive at a sink not later than an individual time limit. Such repeater trees can be modeled as rectilinear Steiner trees with length restrictions between a distinguished root and the terminals. In this talk, we present the first combinatorial polynomial time algorithm that computes a shortest embedding of a given rectilinear Steiner tree considering length restrictions. A key observation is that there always exists an optimal embedding where all vertices are placed on half-integral positions if all terminal positions and length restrictions are integral. This leads to an algorithm using a combination of binary search and dynamic programming.

■ WD-08
Wednesday, 14:30-16:00 - TIC Conference Room 2, Level 3

MAI: One-to-one mentoring for practitioners

Stream: Making An Impact 2 (MAI 2)
Invited session
Chair: *Rosemary Byde*

1 - One-to-one mentoring for practitioners

In this session, you can receive 20 minutes of one-to-one mentoring with an experienced practitioner, on issues you may be facing in your practice, career or development. Possible issues may include: Managing your development and career ● Switching sectors ● Changing jobs ● Transitioning from technical 'doer' to managing technical teams ● Finding the right mentor ● Making contacts, building a network ● Getting recognition when you're a technical expert ● Writing a good CV and doing well in interviews

Managing your team ● Recruiting, training, rewarding and retaining the right people ● Making sure your modellers spend their time modelling ● Delegating without tears ● Inspiring others

Making more of an impact ● Selling your services ● Communicating technical results ● Influencing non technical people ● Getting projects implemented

To get the most from the session, you should do some preparation in advance: ● Think about a problem you'd like help and advice on ● What would you like to know from your mentor? ● Expect to ask questions ● Show an interest in your mentor.

This session is only available to people who have signed up in advance via the 'Making an Impact' (MAI) desk. It is one of three similar sessions.

■ WD-09
Wednesday, 14:30-16:00 - TIC Conference Room 3, Level 3

MAI: Two workshops: Soft side of simulation and Turning ideas into solutions

Stream: Making An Impact 2 (MAI 2)
Invited session
Chair: *Frances Sneddon*
Chair: *Ian Seed*

1 - The soft side of simulation
Frances Sneddon

Simulation is a powerful analytical technique powered by complicated mathematical and statistical algorithms. Operational simulations I've built have typically been validated to 99% accuracy compared to the real world, as an operation tool that's vital. But.........not all simulations have to be that accurate to provide value.

Simulation is an analytical tool yes. It is also a facilitation tool that engages all in problem solving. It is the lead negotiator providing an unbiased point of view that encourages cross team collaboration. It is the exploration vehicle that uncovers unknowns and sparks new ways of thinking.

There is no need to be a simulation expert to build quick and easy models that add real value and insight. Join me to explore how you can leverage the soft benefits of simulation on your projects.

2 - How to turn IDEAS into SOLUTIONS fast
Ian Seed

The purpose of the workshop is to demonstrate an enhanced brainstorming process. These tools will quickly take you from problem definition to a number of practical, workable ideas to solve the problem. The tools are ones that participants will be able to take back and use in their day-to-day business for solving problems and closing gaps. This workhop is suitable for project leaders, anyone involved in forming and managing brainstorming sessions, and anyone interested in enhancing their brainstorming experience.

■ WD-10
Wednesday, 14:30-16:00 - TIC Conference Room 4, Level 3

Forestry and Sustainable Management

Stream: OR in Agriculture, Forestry and Fisheries
Invited session
Chair: *Marina Segura*

1 - Multi-criteria analysis techniques to prioritise indicators for sustainable forests management. Comparing the answers of stakeholders and experts

Pablo Valls-Donderis, María C. Vallés, Francisco Galiana

A set of criteria and indicators for sustainable forest management (SFM) under Mediterranean conditions applicable at the forest management unit scale have been identified. In order to verify and prioritise the indicators, two processes have been carried out: a participatory process to rank the indicators in each criterion according to stakeholders' preferences for a specific forest management unit; and an analytical hierarchy process (AHP) questionnaire with experts to assess the relevance of the indicators for monitoring SFM.

Results show differences in preferences of experts and stakeholders which raise the question of who might be considered for decision-making. The answers are analysed and recommendations are made on which topics might be asked to experts and which ones to stakeholders. Experts are suitable for technical matters like hydrological regulation or carbon sink function, whereas issues such as recreation or maintenance of the visual character are suited for stakeholders.

2 - On solving short-term harvest planning problem using column generation

Pablo González-Brevis, Tomás Pacheco Riedel

In the short-term harvest planning problem, one has to select which areas to harvest and to which teams assign each haversting area at every period so some product demands are met and some cost function is minimized. In this talk, a new linear programming model to solve this problem will be presented. Results considering different solution strategies will be shown. Moreover, a Dantzig-Wolfe decomposition and column generation approach will be addressed. Preliminary computational results showing the benefits of using column generation in this context will be shown.

3 - Territorial and environmental evaluation of intensive livestock farms by using multi-criteria techniques

Consuelo Calafat Marzal, Áurea Gallego Salguero, Israel Quintanilla, Concepcion Maroto

Laws and regulations for the livestock sector have been changed over the last decade with important effects on the farm management as well as on sectorial planning. Intensive livestock sector in Valencia is based mainly on pig and poultry farms. This region is very dynamic regarding urban and industrial development, population growth and agricultural activities. Due to this land use problems have increased. The lack of previous environmental requirements in this region has caused a high concentration of facilities in some areas, and urban sprawl has resulted in many farms being located in problematic areas that are close to villages or towns, residential areas, and protected areas. Conflicts arising from land use and environmental issues have caused problems in the region for many years. The current laws and regulations focus on defining minimum distances between farms, urban centres and/or other farms, and on urbanistic qualification in order to regulate livestock farms in this territorial scope. The objective of this study is to assess Valencian livestock taking into account the legal and environmental framework. GPS has been used to obtain the main data to assess 1200 pig farms and 800 poultry farms and analyse them with multiple criteria analysis. In particular, the weights of criteria have been determined from stakeholders by using AHP. Finally, PROMETHEE method has allowed classifying farms in order to support agricultural policy decisions.

4 - A hybrid multiple criteria method to assess Ecosystem Services

Marina Segura, Concepcion Maroto, Valerie Belton, Concepción Ginestar

The aim of this work is to develop a methodology for classifying forest areas based on the main functions of the ecosystem, thus providing relevant information to assess intangible and non-market services by integrating technical data and social preferences. Firstly, AHP is used to identify the relevant ecosystem services and elicit stakeholder preferences on their importance in the management of protected areas. Secondly, PROMETHEE is applied in a novel way in order to provide aggregated indicators for the three main categories of the ecosystem services (production services, ecosystem maintenance and direct to citizens). The valuation of natural protected areas should be done from the point of view of the supply according to the new regulation framework, in contrast to the contingent valuation that deals with this problem from demand approach. The relevance of the methodology proposed is twofold. On the one hand, it provides basic indicators

to determine the economic compensation to natural disasters such as forest fires, spills, floods... On the other hand, it allows informing the distribution of the available budget and establishing payments for environmental services in order to balance ecosystem services and improve the sustainability of natural areas. Finally, the proposed multiple criteria methodology has been applied in a case study in a Mediterranean Natural Park in Spain.

■ WD-17

Wednesday, 14:30-16:00 - TIC Conference Room A, Level 9

Supply Network Risk 3

Stream: Supply Network Risk and Resilience
Invited session
Chair: *John Quigley*

1 - Optimisation of Surveillance on Supply Networks

Bart MacCarthy, Guven Demirel, Guven Demirel

Surveillance of supply networks typically includes a set of monitoring and control efforts such as financial checks, periodic audits, quality control programmes, and production readiness tests. These are employed to meet objectives including assessing production and management capability of suppliers, ensuring compliance with regulations, checking conformance with quality requirements and design specifications, and assuring on-time delivery. Considering that a prime company in a supply network has only limited time, personnel and financial resources for surveillance and that different suppliers are typically exposed to different types of risks at different degrees, allocating and deploying the right type and amount of surveillance to the right place on the supply network is crucial. In this study, we introduce an optimisation problem in order to determine the optimal allocation of the types of surveillance and company personnel to a given set of critical suppliers. We collaborate with an industry leading company to estimate the costs and effectiveness of different types of surveillance. We provide a systematic investigation of the optimal surveillance plan by analysing its sensitivity to the surveillance resources and effectiveness parameters, as well as discovering patterns of assignment between supplier profiles and surveillance types. Policy recommendations are provided for an effective surveillance plan.

2 - Acceptance Sampling for Surveillance on Supply Networks

Guven Demirel, Bart MacCarthy

Supply networks have become increasingly complex and global, exposing them to many risks as seen in several well-known incidents. Resilience of supply networks has consequently become a topic of critical importance. Industry-wide efforts are being made to understand supply network structures and to increase visibility and traceability in such networks. Although these strategies are valuable, alone they are insufficient. Effective surveillance strategies are needed that can monitor suppliers across the network, which is the focus of this work. Here we consider a surveillance programme in the form of an acceptance sampling scheme applied to a supply network. The aim is to detect non-conformances within the supply network in a situation where final products are also inspected by an authority such as a government body. We develop analytical models and simulations to analyse the success of the surveillance programme, which we define as the likelihood of detecting non-conformance within the supply network before detection by the authority. We examine the success of the programme with respect to the rate of non-conformance, surveillance protocol, authority inspection frequency, supplier position in the supply network, and ordering policy parameters. The systematic analysis reveals new insights on the problem when approached from the perspectives of different network entities -the supplier, prime company, and authority— and leads to policy recommendations for each party.

3 - Risk in Global Production Networks: Evaluation of Inoperability Under Uncertainty

Ali Niknejad, Dobrila Petrovic, Keith Popplewell

This paper concerns Global Production Networks (GPNs) where actors across the globe including suppliers, manufacturers and distributors, collaborate and are interconnected to facilitate the provision of product and service. While these global relationships are quite advantageous, they also leave GPNs vulnerable to various types of regional risks such as political or economic issues in the involved regions as well as the internal risks such as insolvencies or machine breakdowns.

A Dynamic Fuzzy Inoperability Input Output Model (FIIM) is proposed to facilitate evaluation of different GPN configurations in terms of their susceptibility to risk on strategic level. A risk scenario is defined to specify the sequence of disruptive events, their timing, zones of effect and the consequent perturbations of network nodes. A number of criteria to model interdependencies between nodes are identified, such as substitutability of the product, substitutability of the supplier and distance/lead times. They are considered using a multi-criteria method. The criteria are given fuzzy values, such as very low, low, medium, high and very high. The FIIM model determines fuzzy inoperability of nodes, due to the propagation of risk, as well as fuzzy loss of risk. An example from food industry is analysed where two alternative network configurations are compared to illustrate the application of the proposed model.

4 - Modelling Supply Chain Resilience in the Presence of Disruption
Ozias Ncube, Venkata Yadavalli

Complex supply chains are susceptible and hence vulnerable to various disruptions. Although some disruptions occur infrequently, it is imperative that their profile be examined, so as to understand the extent of impact. In this paper, a stochastic model is used to profile supply chain disruption. The disruption profile is premised on the following parameters: source, impact and likelihood of occurrence. A supply chain resilience model is proposed which acts as a contingency or mitigation strategy for each combination of parameters. This creates the platform for a sustainable supply chain. A simulated example is used to illustrate the performance of this model at operational, strategic and financial levels.

■ WD-25

Wednesday, 14:30-16:00 - John Anderson JA3.14 Lecture Theatre

Deterministic Global Optimization

Stream: Global Optimization
Invited session
Chair: *Julius Zilinskas*

1 - Computational models and hard global optimization problems
Panos Pardalos

Most of the conventional computer models are based on the von Neumann computer architecture and the Turing machine model. However, quantum computers (several versions!), analog computers, dna computers, and several other exotic models have been proposed in an attempt to deal with intractable problems. We are going to give a brief overview of different computing models and discuss several classes of optimization problems that remain very difficult to solve. Such problems include graph problems, nonlinear assignment problems, and global optimization problems. We will start with a historical development and then we will address several complexity and computational issues. Then we are going to discuss heuristics and techniques for their evaluation.

2 - Multiparametric mixed-integer quadratic programming: the exact solution
Richard Oberdieck, Efstratios Pistikopoulos

Multiparametric programming involves the solution of an optimization problem as a function of bounded parameters. The solution is thereby composed of (i) the partition of the bounded parameter space into so-called critical regions and (ii) the optimal objective function associated with each critical region as a function of the parameters. For the case of multiparametric mixed-integer quadratic programming (mp-MIQP) problems, the critical regions may be non-convex and in general a number of global optimization issues arise due to the presence of integer variables.

In this contribution we present an algorithm for the exact solution of mp-MIQP problems. Based on the decomposition algorithm, which determines a candidate integer solution via global optimization, it uses suitable affine relaxations on the critical region to generate a polyhedral outer approximation of quadratically constrained critical region. After the solution of the multiparametric quadratic programming (mp-QP) subproblem and the comparison with the current best upper bound,

this relaxation is removed and the original quadratic constraints are reintroduced. Any redundant critical regions are removed by a spatial branch-and-bound strategy, and the next iteration is performed until the termination criteria is met. The proposed strategy is elucidated using several motivating example, also providing computational comparisons with existing strategies.

3 - Extended branch-and-sandwich algorithm for nonlinear bilevel problems
Remigijus Paulavicius, Polyxeni-Margarita Kleniati, Claire Adjiman

Bilevel optimization constitutes a very challenging class of optimization problems, where the inner optimization problem is nested within the outer problem. There are many applications of bilevel optimization in a variety of economic and engineering problems. Special cases of bilevel problems, such as problems in which the inner problem is linear, have been studied extensively and many algorithms have been proposed in the literature. However, the general nonconvex form is a very challenging problem. A new deterministic global optimization algorithm, named Branch-and-Sandwich (B&S), was recently proposed for optimistic bilevel programming problems that satisfy a regularity condition in the inner problem. The theoretical properties of the proposed B&S algorithm and promising preliminary numerical results were investigated in previous work.

In current work, we describe extensions to the B&S algorithm within the MINOTAUR framework and present extended experimental results based on the computational performance of the B&S algorithm on a number of original and literature test problems. We investigate the impact of different algorithmic options, e.g. node management and branching.

4 - Global optimization for engineering structures
Julius Zilinskas

Several Lipschitz optimization algorithms without the Lipschitz constant are proposed recently. Such global optimization algorithms are well suited to black box optimization problems, including problems for engineering structures when there is no analytical expression of objective or constraint functions since the structures are modeled by finite elements. In this talk we discuss results of global optimization algorithms on problems of engineering structures and ways to improve the performance.

■ WD-26

Wednesday, 14:30-16:00 - John Anderson JA3.17 Lecture Theatre

Interior Point Methods and Applications

Stream: Convex, Semi-Infinite and Semidefinite Optimization
Invited session
Chair: *Lilian Berti*

1 - Computing the splitting preconditioner for interior point method using an incomplete factorization approach
Aurelio Oliveira, Marta Velazco

The splitting preconditioner is very effective when applied together with the conjugate gradient method in the final iterations of interior point methods for linear programming. However, the preconditioner may be expensive to compute since it needs to find a set of linearly independent columns from the constraint matrix in order to build a non singular matrix. In this work a new version of the splitting preconditioner is computed waiving the need to obtain a non singular matrix since the controlled Cholesky factorization will be used to compute the preconditioner from the normal equations of a smaller set of columns. Such an approach is practicable since the controlled Cholesky factorization can compute a factorization of a non singular matrix by adding a suitable diagonal perturbation. Numerical experiments show that the new approach improves previous performance results for both robustness and time on some large-scale linear programming problems.

2 - A new approach in direct solution of linear systems arising from interior point methods

Luciana Yoshie Tsuchiya, Aurelio Oliveira

Primal-Dual interior point methods appeared on linear programming as an alternative to Simplex method, showing efficient for solving large-scale linear programming problems. At each iteration of these methods is necessary to solve a linear system. In real life applications this system usually has higher dimensions and a high degree of sparsity. Its solution is the most expensive step of such methods. The approach most commonly used to solve it is the the Cholesky factorization. For problems where the Cholesky factorization loses sparsity, iterative methods such as the preconditioned conjugate gradient are used. A preconditioner sometimes used in the second approach, is the controlled Cholesky factorization (CCF), which consists of an incomplete Cholesky factorization such that the density of the triangular matrix L obtained in factorization is conveniently controlled by an parameter. The goal of this work is to improve the direct method approach replacing the Cholesky factorization by the controlled Cholesky factorization. In early iterations, we can obtain the approximate directions of the original direction, adopting a value of CCF parameter such that the matrix obtained in factorization is very sparse, speeding up the linear system solution. In later iterations we compute a CCF factorizations closer to the Cholesky factorization, in such a way that the method's convergence is not affected.

3 - Continued iteration on predictor corrector interior point method for linear programming

Lilian Berti, Aurelio Oliveira, Carla Ghidini

In this work, the continued iteration is used with the predictor corrector interior point method in order to reduce the total computational time that it leads to obtain an optimal solution of the linear programming problem. The continued iteration can be interpreted as the projection of the search direction, already determined by the interior point method. It consists in determining a new direction to the method and can be used in two different forms, before or after of a complete iteration. The new direction, called continued direction, is computed with lower effort compared to a method iteration. Thus, although there is an increase of the computational effort per iteration to use the continued iteration, the expected reduction in the number of iterations, enables the reduction of the total computational time. Some proposals for the continued direction are developed with the purpose of increasing the reduction of primal and dual infeasibility in each iteration of the predictor corrector method. A comparison of the computational results with large-scale problems for the predictor corrector method with and without continued iteration is performed, showing that the method obtain a good performance using the proposed technique.

■ WD-27

Wednesday, 14:30-16:00 - John Anderson JA3.27, Level 3

Emerging Applications in Game Theory and Management 1

Stream: Emerging Applications in Game Theory and Management
Invited session
Chair: *Vladimir Mazalov*
Chair: *Leon Petrosyan*

1 - Cooperative Solutions in Ranking Problem of Alternatives

Vladimir Mazalov, Aleksey Kondratev

The present paper focuses on the ranking problem of candidates for a certain position based on ballot papers filled by their supporters. Such problem arises during elections of a president, a professor in a chair and many other positions. We suggest a ranking procedure of alternatives using cooperative game theory methods. For this, it is necessary to construct a characteristic function via the filled ballot paper profile of voters. The Shapley value serves as the ranking method. The winner is the candidate having the maximum Shapley value. And finally, we explore the properties of the designed ranking procedure.

2 - Cooperative Great Fish War Model with Asymmetric Exploitation Times

Anna Rettieva, Vladimir Mazalov

Discrete-time game-theoretic models related to a bioresource management problem (fishery) are investigated. The players are countries or fishing firms that harvest the fish stock. Players differ in their time preferences, and use different discount factors. Furthermore, the players have different planning horizons. Two variants are considered: fixed and random harvesting times. The main goal here is to construct the value function for the cooperative solution and to distribute the joint payoff among the players. We propose to use the Nash bargaining solution to determine cooperative behavior.

■ WD-28

Wednesday, 14:30-16:00 - John Anderson JA3.26, Level 3

General Results Related to Convex Optimization

Stream: Convex Optimization
Invited session
Chair: *Erdem Kilic*

1 - A relaxed projection algorithm for constrained equilibrium problems

Susana Scheimberg, Paulo Sergio Marques Santos

We propose an iterative algorithm to solve the Constrained Equilibrium Problem, (CEP). This formulation contains, as particular instances, the Constrained Variational Inequality problem considered by Censor, Gibali and Reich (Numerical Algorithms, 2011), the Split Equilibrium Problem studied by Z. He (J. of Ineq. and Appl., 2012) and the classical Equilibrium Problems. At each iteration, the algorithm calculates one projection onto the viable set of the equilibrium problem and two explicit projections onto suitable half-spaces. Convergence properties of the method are established under mild assumptions. Some numerical results are reported.

2 - Evolutionary Variational Inequality Formulation of Generalized Nash Equilibrium Problem

Rachana Gupta, Didier Aussel, Aparna Mehra

For time dependent genaralized Nash equilibrium problem a reformulation in evolutionary variational inequality is proved in the general setting of quasiconvex decision functions. An existence result for time dependent generalized Nash equilibrium problem is deduced and application to dynamic electricity market is also considered.

3 - Two-Stage Optimization-Based Framework for Unequal-Areas Facility Layout Problem

Manuel V. C. Vieira, Miguel Anjos

The unequal-areas facility layout problem is concerned with finding the optimal arrangement of a given number of non-overlapping indivisible departments with unequal area requirements within a facility. We present an improved optimization-based framework for efficiently finding competitive solutions for this problem. The framework is based on the combination of two mathematical optimization models. The first model is a nonlinear approximation of the problem that establishes the relative position of the departments within the facility, and the second model is an exact convex optimization formulation of the problem that determines the final layout. Aspect ratio constraints on the departments are taken into account by both models. Our computational results show that the proposed framework is computationally efficient and consistently produces competitive, and often improved, layouts for well-known instances from the literature as well as for new large-scale instances with up to 100 departments.

4 - Hermite-Hadamard-Fejér type inequalities for m- convex functions

Jose Gimenez, Mireya Bracamonte, Nelson Merentes, Miguel Vivas

In this paper we present some generalizations of the classical inequalities of Hermite-Hadamard-Fejér for m-convex functions.

■ WD-29

Wednesday, 14:30-16:00 - John Anderson JA4.12, Level 4

MINLP for Air Traffic Management problems

Stream: Mixed-Integer Nonlinear Programming
Invited session
Chair: *Frederic Messine*

1 - A decomposition algorithm for air conflict detection and resolution using speed control
Sonia Cafieri, David Rey

We address the conflict detection and resolution problem in air traffic control. To ensure the safety of aircraft throughout their flight, air traffic controllers continuously monitor aircraft trajectories, anticipating any potential loss of separation, known as conflict, and issuing appropriate conflict resolution maneuvers. Due to the forecasted increase in air traffic volume, the automation of conflict detection and resolution procedures is receiving a growing attention. The aircraft separation problem can be represented using mathematical programming and most approaches rely on the discretization of time or space to approximate the separation constraints with linear functions. We focus on aircraft separation by speed control and propose a novel approach based on mixed integer programming to solve a maximum number of potential conflicts. Unlike previous work, the proposed methodology does not require any form of discretization, which results in a compact nonlinear mixed integer program. We propose a decomposition scheme to improve the computational sustainability of the of the model. The detection of potential conflicts is carried out in a preprocessing phase where pairwise conflicts are identified before a complete model, i.e. with all aircraft, is solved. Numerical results show that the proposed algorithm is able to find competitive solutions.

2 - Aircraft deconfliction by sequentially applying velocity and heading angle changes
Riadh Omheni, Sonia Cafieri

We consider the aircraft conflict detection and resolution problem, that is crucial in Air Traffic Management. An aircraft conflict arises when a potential loss of separation between aircraft trajectories occurs. We propose optimization models based on a combination of aircraft velocity and heading angle changes to avoid conflicts. The developed models are mixed 0-1 nonlinear programs that are solved sequentially. The main nonlinarities are reformulated to speed up the resolution. Numerical results, obtained by using state-of-the-art solvers, are presented to validate the proposed approach.

3 - An Interval Branch and Bound algorithm dedicated to air conflict avoidance problems with speed changes
Frederic Messine, Sonia Cafieri, Ahmed Touhami

In this work, the interval-Branch-and-Bound global solver IBBA is adapted to solve air conflict avoidance problems. We consider only changes on aircraft speeds to separate aircraft trajectories and so avoid conflicts. The problem is formulated as a MINLP, with a convex quadratic objective function. IBBA works using linear relaxations of the initial nonlinear and nonconvex MINLP in order to compute bounds. In this work, the main idea is to keep the convex quadratic objective function and linearize only the constraints (using affine arithmetic techniques). Then, the quadratic convex problem is solved using CPLEX. Mc-Cormick relaxations are also proposed and provide actually the best results. A suitable choice of the branching variables is also discussed to enhance the efficiency of the Branch-and-Bound for the considered application. Numerical results show that it is in fact possible to improve considerably the efficiency of the considered Branch-and-Bound to solve the addressed problem.

■ WD-30

Wednesday, 14:30-16:00 - John Anderson JA5.02, Level 5

OR and the Arts

Stream: OR and the Arts
Invited session

Chair: *Vitaly Podobedov*
Chair: *Gerhard-Wilhelm Weber*
Chair: *Pakize Taylan*
Chair: *Sadia Samar Ali*

1 - On the intriguing number 1,001
Jakob Krarup

Born in 1936 I was a schoolboy on the threshold of the secondary school when a knapsack-type game was played with a class mate around 1946-47. To play the game well and fascinated by numbers in general since my early childhood, however, I realized soon the usefulness of knowing that $1,001 = 71113$. Today, about 70 years later, the game has been passed to some of my grandchildren who also should convince themselves that simple, arithmetic calculations do not necessarily require a pocket computer. As a side effect of the recent revival of the game I felt motivated to seek more insight into the intriguing number 1,001. An account of the findings is provided.

2 - Evolutionary Algorithm for Multidimensional Scaling
Agn Dzidolikait

In this paper genetic algorithm for multidimensional scaling is analyzed. Genetic algorithm mimics natural evolution. Multidimensional scaling method is used to visualize multidimensional data into a lower-dimensional space while keeping the structure of the original data such as clusters and outliers. Here the genetic algorithm and multidimensional scaling are combined. The hybrid algorithm is used to experiment with beverages and pharmacological datasets, and certain features are noticed.

■ WD-31

Wednesday, 14:30-16:00 - John Anderson JA5.04, Level 5

Computation and Computational Design

Stream: Algorithms and Computational Optimization
Invited session
Chair: *Andreas Elias*

1 - Benders Decomposition Applied to Cooperative Lot-Sizing
Andreas Elias, Alf Kimms

A lot-sizing problem in the context of purchasing alliances is considered. We focus on a supply chain which consists of several retailers and multiple suppliers. The retailers are free to cooperate in order to benefit from quantity discounts. In case of a cooperation, transshipments are possible, that is, movement of a product from one retailer to another. A mixed-integer programming problem is introduced to cope with the optimization problem of material flows. Our goal is to minimize the total cost of the system. A Benders decomposition approach and a modified Benders decomposition approach are applied to find a solution to this problem. Furthermore, a model reformulation using special ordered sets (type 1) is presented. The performances of the different solution methods and problem formulations are examined in a computational study.

2 - The Collaborative Assignment Problem: Using Pseudo Dual Decomposition to Solve Distributed Binary Linear Programs
Julian Wulf

Mathematical decomposition has the ability to achieve decentralised coordination in distributed environments. The required problem structure is given in most real world application domains, and the information exchange is limited to dual values if Dantzig-Wolfe decomposition is applied. But the non-sensitivity of dual values is questionable, as they account for scarcities and thus should be kept private in settings where information asymmetries exist. We use pseudo dual decomposition, which is generally applicable to distributed binary linear programs and omits the exchange of dual values. These are turned into decision variables and are determined endogenously by the sub-broblems itself in an inverse optimisation approach. The procedure is applied to the collaborative assignment problem where two or more parties assign individual tasks to a common pool of workers. The described setting can be traced back to an instance of the well-known

assignment problem. It shares its totally unimodular coefficient matrix and enables the scheme to yield proven optimal solutions. To analyse the performance of the scheme, computational tests have been conducted, which highlight its efficiency in terms of exchanged proposals.

3 - Analysing Exact Approaches to the Transmission Expansion Planning Problem with Redesign
Pedro Henrique González, Philippe Michelon, Luidi Simonetti, Carlos Martinhon

Due to the growth of energy demand over the years, it becomes necessary for the managing entities to evolve the electrical power system, adding new transmission lines and power generators. Since transmission lines are expensive to build, one would like to build new generating units. However, usually it is not possible or not economical to build the new generating units close to consumption centers, therefore those units must be constructed in distant places. Consider for instance Brazil's situation. The country possesses large resources in hydropower. Nevertheless, those are usually located far a way from main cities and industries. Consequently, it is necessary to expand the transmission network. The extreme difficulty to solve the Transmission Expansion Planning Problem with Redesign exactly is the motivation for this work. We developed and tested two exact approaches as alternatives for the straightforward resolution of the mathematical formulation. The developed exact methods are a Benders decomposition and a method that we call ring partition search. Computational experiments shows the impact of each method in comparison to the straight forward application of the mathematical formulation.

■ WD-32
Wednesday, 14:30-16:00 - John Anderson JA5.05, Level 5

Portfolio selection and management science

Stream: Emerging Applications in Portfolio Selection and Management Science
Invited session
Chair: *Sebastian Utz*

1 - Tri-Criterion Modeling for Constructing More-Sustainable Mutual Funds
Sebastian Utz, Maximilian Wimmer, Ralph E. Steuer

One of the most important factors shaping world outcomes is where investment dollars are placed. In this regard, there is the rapidly growing area called sustainable investing where environmental, social, and corporate governance (ESG) measures are taken into account. With people interested in this type of investing rarely able to gain exposure to the area other than through a mutual fund, we study a cross section of U.S. mutual funds to assess the extent to which ESG measures are embedded in their portfolios. Our methodology makes heavy use of points on the nondominated surfaces of many tri-criterion portfolio selection problems in which sustainability is modeled, after risk and return, as a third criterion. With the mutual funds acting as a filter, the question is: How effective is the sustainable mutual fund industry in carrying out its charge? Our findings are that the industry has substantial leeway to increase the sustainability quotients of its portfolios at even no cost to risk and return, thus implying that the funds are unnecessarily falling short on the reasons why investors are investing in these funds in the first place.

2 - Cardinality constrained portfolio optimization via mixed integer linear programming
Nasim Dehghan Hardoroudi, Abolfazl Keshvari, Markku Kallio, Pekka Korhonen

Given a large number of assets in a mean-variance portfolio problem, the number of active assets at a non-zero level in an optimal portfolio tends to be large and often unattractive to implement. Controlling the number of active assets (cardinality of the portfolio) in a mean-variance portfolio problem is practically important but computationally difficult. Such task is commonly presented as a mixed integer quadratic programming (MIQP) problem. We propose a novel approach to reformulate such problem as a MILP problem. Our proposed formulation can be solved by standard MILP solvers much faster than the MIQP problem. For numerical illustration, we construct cardinality

constrained minimum variance portfolios of stocks in S&P500 using upper limits 2, 3, 5 and 10 for cardinality and a dense set of target levels for expected return. We depict the minimum variance portfolios in a portfolio map on the mean-variance diagram. Such a map is useful for subjective evaluation of investment alternatives: compared with traditional mean-variance efficient frontiers, portfolio map is an improvement as cardinality of the portfolio provides an important third criterion in addition to risk and return.

■ WD-33
Wednesday, 14:30-16:00 - John Anderson JA5.06, Level 5

Linear and Combinatiorial Multiobjective Optimization

Stream: Multiobjective Optimization - Methods and Applications
Invited session
Chair: *Kuan-Min Lin*

1 - Determination of Optimal Buffer Sizes in Unreliable Production Lines: A Multi-objective Tabu Search Approach
Leyla Demir, Semra Tunali

This study presents an application of a multi-objective tabu search approach to solve the buffer allocation problem in unreliable production lines. The buffer allocation problem is an NP-hard combinatorial optimization problem dealing with finding optimal buffer sizes among the machines in a production line so as to maximize throughput of the line or minimize total buffer size in the system. The aim of this study is to minimize total buffer size while maximizing the production rate, i.e. throughput rate of the line. The production rate of the line is evaluated by the well-known decomposition method and the buffer sizes are optimized by an adaptive tabu search procedure. Using the Pareto-dominance concept inefficient solutions are eliminated by the proposed search procedure. A computational study is carried out to show the efficiency of the proposed solution approach on a wide range of problem sets. Very promising results are obtained from this computational study.

2 - Finding the Nadir Point of a Multi-objective Linear Programme
Zhengliang Liu, Matthias Ehrgott

The nadir point is characterized by the componentwise maximal values of the nondominated points of a multi-objective optimization problem (MOP). The significant importance of determining the nadir point is widely recognized because it is a pre-requisite of a number of optimization problems such as compromise programming. It also facilitates the normalization of the objective functions of a MOP, which is a vital task for multi-criteria decision making (MCDM) procedures. However, it is challenging to locate the nadir point. Although numerous estimation methods have been introduced, a more reliable and accurate approach is to be pursued. In this paper, we propose two exact methods to find the nadir point of multi-objective linear programmes (MOLPs). They are based on a primal and a dual methods of maximizing a linear function over the nondominated set of a MOLP problem. Computational experiments were performed to test the new methods against another exact method from the literature. The results reveal that the new methods find the nadir point more efficiently.

3 - Desirability Function Approach to Multiobjective Optimization Problems
Gokce Baysal, Ipek Deveci Kocakoç

The main objective of this paper is proposing a new method to select an appropriate point on hypervolume Pareto-optimal set. The proposed method uses an adapted desirability function and is applied on test functions and real world problems in literature. Results show that this adapted-desirability function provides help in selecting an optimum point in Pareto-optimal set. Especially, this method reaches a better solution point than that of Pareto-optimal set in constrained case. The adapted-desirability function is suggested as a method to be used together with multiobjective optimization by evolutionary algorithms as a support for decision makers instead of an alternative method to it.

4 - Multiobjective Column Generation using the Revised Normal Boundary Intersection Method: An Application to Radiotherapy Treatment Planning Optimisation

Kuan-Min Lin, Andrea Raith, Matthias Ehrgott

We propose a column generation based approach to compute a representative set of nondominated points of multiobjective linear programmes. The method implements column generation within the revised normal boundary intersection (RNBI) framework which is based on projecting a set of equidistant reference points onto the nondominated set to form a representative set of nondominated points. To find the projected points, one needs to solve an RNBI subproblem for each of the reference points. In this study, the RNBI subproblems are solved by column generation. The column generation process adds variables to the restricted master problem which moves a current objective point towards the nondominated set. Different initialisation approaches for column generation are implemented, including the so-called Farkas pricing, which provides a mechanism to conclude the infeasibility of an RNBI subproblem. A reference point bounding method is proposed to eliminate reference points that lead to infeasible RNBI subproblems. Numerical tests on a radiotherapy treatment planning problem demonstrate that the RNBI method with column generation can achieve solutions close to optimality with a small number of variables.

■ WD-39

Wednesday, 14:30-16:00 - Colville C405, Level 4

Preference Learning III

Stream: Preference Learning
Invited session
Chair: *Roman Slowinski*

1 - Entropy-optimal weight constraint elicitation with additive multi-attribute utility models

Tommi Tervonen, Gert van Valkenhoef

We consider the elicitation of imprecise preference information for the additive utility model in terms of linear constraints on the weights. We propose a framework for comparing holistic preference elicitation questions based on their expected information gain, and introduce a procedure for approximating the optimal pair-wise comparison question. We extend the basic approach to generate reference alternatives that differ on only a few attributes, and to determine when further preference information is unlikely to reduce decision uncertainty. We present results from computational experiments that assess the performance of the procedure and assess the impact of limiting the number of attributes on which the reference alternatives differ. The tests show that the proposed method performs well, and when implemented in a decision support system it may substantially improve on-line elicitation using pair-wise comparisons.

2 - Evaluation of predictive accuracy for pairwise prediction problems

Antti Airola

A common type of prediction problem appearing in the machine learning preference learning and ranking literature is that of predicting orderings over pairs of objects. For example, a developer of a web search engine might want to rank how well user queries and documents match together, while in a common application in computational medicine one needs to predict which drug-target pairs are most likely to interact together. Given a training set of object-pairs with known labels, one may train a machine learning method that can make predictons for out-of-sample pairs. When considering how to estimate the predictive accuracy of such a model, we can recover four distinct settings based on our assumptions about both, one or none of the objects in test pairs being part of our training set. In this talk I will present these settings, discuss how to properly use cross-validation for accuracy estimation in different settings, and present experimental results.

3 - Fast Gradients for Tensor-Based Preference Learning with Sparse Training Labels

Tapio Pahikkala

A large portion of preference learning problems can be cast under the framework of learning with pair-input data, also referred to as dyadic prediction. Typical examples are information retrieval problems, where the input consist of a query and an object part, full cold-start collaborative filtering tasks with data consisting of consumer-product pairs, and certain interaction prediction problems in bioinformatics, where one aims to predict, for example, which drugs will interact with given proteins the most. It has been shown by various authors that models based on tensor product features and kernels are powerful and computationally efficient for solving this type of tasks. In this talk, I present a new algorithm for training tensor product kernel models for preference learning with paired inputs. It is shown that taking simultaneously advantage of both the sparsity of training labels and the well-known vec-trick for tensor-product kernels can considerably accelerate the training process beyond the state-of-the-art.

4 - Efficient Top-K Prediction for Multi-Target Problems

Krzysztof Dembczynski, Michiel Stock, Bernard De Baets, Willem Waegeman

In many multi-target problems we are interested in predicting the top k best items. For example, in collaborative filtering, we would like to recommend the k most preferred movies to a user, in multi-label classification, we want to predict the k most probable labels, and in biological network inference we aim to find the k best-binding molecules for a given protein. A naive approach would require computing a score for each possible item, sorting the items according to the scores, and selecting the top k items. To avoid the computation of the score for each possible item, we can follow a more intelligent strategy that will minimize the number of tested items. We verify two such algorithms, originally introduced in the fields of databases and information retrieval, and adapt them to a wide spectrum of machine learning problems.

■ WD-41

Wednesday, 14:30-16:00 - Colville C512, Level 5

MCDA in Energy Planning

Stream: Multiple Criteria Decision Aiding
Invited session
Chair: *Eleftherios Siskos*

1 - Robust evaluation of electricity production investments from renewable energy sources: A synergistic multicriteria approach

Eleftherios Siskos, John Psarras

The necessity for disengagement from conventional energy sources, in association with the increasingly strict measures of the European Union (EU) towards this direction, lead to an imperative promotion and deployment of renewable energy sources (RES) infrastructures. The aim of this paper is to evaluate possible medium-scale investments on electricity production from RES, of approximately 10 MW. Specifically, a multicriteria evaluation system is elaborated, based on four points of view: (i) techno-economic, (ii) social, (iii) environmental, and (iv) political. The investments assessed are categorized with respect to the type of RES invested upon (i.e. solar, wind, biomass, etc.), and the area of implementation (mainland, islands or offshore). The selection of the most preferred investments is achieved through the implementation of the ELECTRE IS method, which is able to handle pseudo-criteria. The criteria weights are elicited with the aid of the revised Simos method, and finally the robustness of the results is measured and analysed. The overall objective of this research work is to support energy policy decision making in Europe and trigger sustainable development. The proposed approach is examined for the case of Greece, which, although having high potential in electricity production from RES, mainly hydroelectric, wind and solar, is still considerably behind in comparison to other EU countries in the area of RES adoption.

2 - A Two-Stage Multi-Criteria Planning for Distributed Wind and Solar Power Integration

Tongdan Jin, Yi Chen

Distributed electric system integrating wind and solar generation is reshaping the landscape of power industry. Distributed renewable generation allows the utility companies to lower the carbon footprints as well as deferring the expansion of grid infrastructure. However, power

intermittency and equipment cost are the main hurdles confining the large adoption of wind- and solar-based energy solutions. This paper proposes a multistage, multicriteria approach maximizing the renewable energy throughput, while minimizing the levelised cost of energy. In particular, we optimize the sizing, siting, and maintenance of renewable sources under stringent reliability, power quality, and environmental constraints. A two-stage meta-heuristics, consisting of genetic algorithms and the gradient method, is developed, in order to search for the non-dominant solution set. A 13-node distribution network is used to demonstrate the performance of the proposed planning model. The results are compared with simulations and other meta-heuristics, and it is shown that the genetic algorithm excels in terms of computational time and quality of the results.

3 - A MCDA model for addressing nearly Zero Energy Buildings (nZEB) design
Giulio Mondini, Marta Bottero, Stefano Corgnati

Decision problems, involving the definition of energy strategies in the context of buildings and districts, are currently addressed with the aid of the cost-optimal methodology, in accordance with the Energy Performance Building Directive of the European Commission, issued in 2010. Following the aforementioned methodology, the financial performance of different energy scenarios is valued with a global cost calculation, which consists of the estimation of the net present value of costs incurring in a defined calculation period, considering residual value of components with longer life-span. The present study aims at expanding the cost-optimal approach, in order to support decision-making processes for sustainable energy. In particular, the paper focuses on the use of Multi-Criteria Decision Analysis (MCDA) methods for the selection of optimal energy systems. Starting from a real case study, located in the city of Torino in Italy, the paper proposes a MCDA model able to fulfill the requirements of the stakeholders, and to include all different dimensions of the problem, such as investment cost, operation and maintenance cost, environmental emissions, technological constrains etc. in the evaluation. The relationship between buildings market value and energy performance is also considered in the proposed evaluation framework, and the robustness of the results is analysed.

■ WD-47

Wednesday, 14:30-16:00 - Graham Hills GH513, Level 5

MAI: Academic-practitioner collaboration round table 2: how can we support it?

Stream: Making An Impact 1 (MAI 1)
Invited session
Chair: *Richard Eglese*
Chair: *Galina Andreeva*

1 - Academic-practitioner collaboration round table 2: How can we support it?
Richard Eglese, Ahti Salo, Daniele Vigo, Ana Isabel Barros, Jean André

This is the second of two round tables on academic-practitioner collaboration. Each of the two session will involve an exchange of views on academic-practitioner collaborations with the objective of designing a blueprint for successful partnerships. The discussion will be led by a panel of academics and practitioners with extensive experience in collaboration. After brief introductions from the panel, the audience will be invited to ask questions and share the views on some of the following topics (the list is not exhaustive): Round table 2: what can we do to support it? ● Building research capacity in OR; ● Different formats of collaboration; ● Specific areas that would benefit from more ac-prac interventions; ● Possible structures to support better interaction.

■ WD-48

Wednesday, 14:30-16:00 - Graham Hilils GH510, Level 5

Applications

Stream: Telecommunication, Networks and Social Net-

works (contributed)
Contributed session
Chair: *Gökhan Sürmeli*

1 - Satisfaction-Loyalty Link in Turkish Mobile Communications Market: The Role of Perceived Switching Costs and Attractiveness of Alternatives
Gökhan Sürmeli

It is crucial for service providers to retain their customer base in today's saturated mobile communications market. Establishing high customer loyalty not only prevents subscribers from switching to other operators but also makes them recommend their service provider to the customers of competitors. Some recent developments such as the introduction of mobile number portability, increased competition among operators, and converging service levels are believed to help eliminating the negative influence of perceived switching costs on switching intention. In this study, the impact of perceived procedural, financial and relational switching costs on customer loyalty and the role of attractiveness of alternative offerings on the relationship between customer satisfaction and customer loyalty are examined using structural equation modeling. The data is based on a survey conducted with GSM subscribers in Turkey.

2 - Ssocial Networks from point of view of industrial engineering
Alp Şenoğlu, Gurkan Ozturk

The aim of the study is to point out potential of social networks and to show that using technics of industrial engineering is one of the most efficient ways for using this potential. For that purpose in this study, relationships of social networks with industrial engineering is examined and a social network application is developed. Economics of social networks, information economics and in which branches of industrial engineering, social networks can be used as a tool topics are elaborated. A social network which lets it's members share real goods with each other, is designed, constructed and started to serve on web by URL:www.durustpaylas.com. This website's operation principals and business processes are showed by diagrams using a business process management standard. A recommendation system which uses a binary similarity algorithm is established on the social network application. A code using saving algorithm to solve vehicle routing problems which can occur on object delivery phase, integrated to the social network

3 - Fuzzy game theory based decision making methodology for network bandwidth allocation
Julija Asmuss

We develop a fuzzy logic based approach proposed by the author at the previous EURO conference for bandwidth management in a network with DaVinci architecture, according to which the physical substrate network is divided into virtual networks to support traffic classes with different performance objectives. Now we show how the methodology introduced for two virtual networks can be developed to the case of multiple networks by extending the decision making system with a new module, which efficiently shares resources among multiple traffic classes using fuzzy game theory based technique. In this framework bandwidth allocation mechanism is considered as a fuzzy game of virtual networks. Each virtual network formulates its decision on the basis of uncertain information. We develop the decision making technique by considering players, which use fuzzy rules to obtain strategic decisions. The effectiveness of the proposed methodology is evaluated within simulation experiments realized by using Coloured Petri Nets Tools.

4 - The impact of recommendation agents' type of voice on users behaviors
Emna Cherif, Jean-François Lemoine

This paper aims to demonstrate the influence that recommendation agent type voice may have on users' reactions. Through experimentation, we compare the effects of human and synthetic voice on perceived social presence, recommendation agent trust, website trust and behavioral intentions. The findings suggest that the human voice is likely to provide a higher level of social presence and recommendation agent trust. The structural equation model shows that social presence has a positive effect both on recommendation agent trust and behavioral intentions. In turn, recommendation agent trust influences website trust and behavioral intentions. Finally, results show that website trust positively impacts behavioral intentions

■ WD-49

Wednesday, 14:30-16:00 - Graham Hills GH511, Level 5

Special Aspects of Location, Logistics and Transportation

Stream: Location, Logistics, Transportation (contributed)
Contributed session
Chair: *Claudia Archetti*

1 - Using clickstream big data to optimize collection and delivery points for online retailer
Haitao Lee, *Yeming Gong*

We use clickstream data to optimize collection and delivery points for online retailers. Our research shows an optimal way to locate collection and delivery points for online retailer. We first use the random forest algorithm in machine learning to predict the number of goods customer buys for each purchase and the purchasing frequencies for each period from clickstream big data, then cluster customers' IP addresses with mixture of Gaussians algorithm. Based on the customers' information, we propose a mathematical model to optimize the location of collection and delivery points.

2 - Reduction of trapezoidal type-2 fuzzy variables and its application to solid transportation problem
Uttam Kumar Bera, *Amrit Das*

This paper is proposed two different type reduction method viz. CV based reduction method and nearest interval approximation method for a trapezoidal type-2 fuzzy variable and shows their application to a solid transportation model. The main aspect of this paper is to derive the reduction process of a trapezoidal type-2 fuzzy number. The first reduction method is based on critical values and the second method is based on alpha-cut of fuzzy number. As an application a solid transportation model with minimizing the cost and time is developed using trapezoidal type-2 fuzzy parameters and solved. Finally after solving the proposed multi-objective problem by intuitionistic fuzzy programming technique, a comparison of the two reduction methods are discussed briefly. The proposed models and techniques are finally illustrated by providing numerical examples at the end. Some sensitivity analysis are prepared and have been discussed the effect of total cost and time with respect to the change of credibility levels of cost, supply, demand, conveyance etc.

■ WD-51

Wednesday, 14:30-16:00 - Graham Hills GH542, Level 5

MAI: Optimising the real world, robustly

Stream: Making An Impact 3 (MAI 3)
Invited session
Chair: *Andrew Harrison*

1 - Optimising the real world, robustly
Andrew Harrison

In this workshop for OR practitioners we give an introduction to formulating and solving robust optimisation problems. We begin by discussing what robust optimisation is and why we would want to optimise robustly; what are the benefits? In the second part, we will explore some simple examples of robust optimisation formulations and close with an exploration of a robust formulation of a problem from power generation. Participants are encouraged to bring along their own laptops and install a temporary copy of the Xpress software so that they can try out some of the examples themselves.

Bring your laptop and you can try the software.

■ WD-52

Wednesday, 14:30-16:00 - Graham Hills GH554, Level 5

Optimization Approach for Risk Measurement and Control

Stream: Financial and Commodities Modeling
Invited session
Chair: *Rosella Castellano*

1 - Measuring Portfolio Diversification Based on Optimized Uncorrelated Factors
Alberto Santangelo, *Attilio Meucci*, *Romain Deguest*

In recent years, the practitioners and academic financial community has witnessed a surge in interest in the concept of risk parity, as well as the broader concept of portfolio diversification management. In traditional risk parity, portfolio diversification is measured in terms of marginal risk contributions from each individual risk factor. Such contributions are spurious, because in reality they contain effects from all the factors at once. Furthermore, there exist no clear metric to quantify the diversification represented by the marginal risk contributions. We propose an alternative approach to risk parity based on the Effective Number of Bets: instead of the marginal contributions from correlated factors, we measure the true contributions from uncorrelated bets. The Effective Number of Bets precisely quantify the diversification level, summarizing in one number the fine structure of diversification contained in the set of uncorrelated bets in a portfolio. Then, we introduce a natural set of uncorrelated bets to manage diversification, the Minimum-Torsion Bets, which are the optimized uncorrelated factors closest to the original portfolio risk factors. The contributions to risk from the Minimum-Torsion Bets constitutes a generalization of the marginal contributions to risk used in traditional risk parity.

2 - An Empirical Investigation of Herding Behavior in European Sovereign CDS Market
Maria Miruna Pochea, *Rosella Castellano*, *Rita D'Ecclesia*

Since 2007, credit markets have witnessed a repricing of credit risk that has affected all sectors. This turbulence reached its peak with the collapse of Lehman Brothers in September 2008, causing large state interventions to control systemic risk and its negative consequences. The Lehman Brothers' event led also to a severe repricing of credit risk of developed countries sovereigns. Especially in the Euro area, sovereign debt markets came under large stress in 2010, causing large sell-offs of risky assets due to "flight to safety' episodes, and upward jumps in CDS quotes. The 2010 sovereign debt crisis has focused scholars' and policy makers' attention to the role of financial investors' activities in CDS market. In particular, some studies have suggested that speculative attitudes among investors could destabilize market quotes and create excessive volatility. The main goal of this paper is to contribute to the discussion on this issue by empirically testing the herding behavior in European sovereign CDS market, arguing that this could be a contributing factor behind the upward jumps in sovereign CDS spreads of some European countries.

3 - Consistent Risk Acceptance Criteria through Networks
Roy Cerqueti, *Claudio Lupi*

In the theory of decisions, projects are usually evaluated in terms of their riskiness, and often risk is intended as the one-shot-type binary choice of accepting or not accepting it. This paper elaborates on the concept of risk acceptance, and aims at developing a theoretical framework based on networks theory. In doing this, the interconnections between the random quantities involved in the decision are taken into account and the relevance of the theme in the context of finance and insurance is also highlighted. The conditions to be satisfied in order to let the risk-acceptance criterion be consistent with the standard axiomatization of the expected utility theory are also explored. In accord to previous literature, we obtain that a risk problem might be meaningful even if it is not consistent with the standard axiomatization of expected utility. Some illustrative examples are also provided.

4 - Concentration in Financial Networks
Giulia Rotundo

This work studies the raise of concentration keeping explicitly into account the presence of financial networks. In fact, the presence on the market of a specific company can be recorded through both

direct and indirect connections to other companies. Indirect connections can be as relevant as heavily modify the actual weight of each single company, and, consequently, changing the actual market concentration. The Herfindahl—Hirschman concentration index is used for explicitly considering the role of the topology of financial economic networks on market concentration. The Herfindahl-Hirschman index plays a significant role in the enforcement process of US antitrust laws. Since 1982, the Merger Guidelines have provided an indication for the identification of post merger markets as unconcentrated, mildly concentrated, or highly concentrated based on the value of HHi , http://www.stanfordlawreview.org/online/obama-antitrust-enforcement. The present analysis serves for overcoming the results already obtained through randomized experiments aiming at understanding to which extent the topology of this financial economic network is constraining the market concentration, so we derive and comment the results on the maximum value of HHi under the scale-free constraint. The case study of the Italian stock market serves for outlining the relevance of the shareholding network in the measurement of effective concentration.

■ WD-53

Wednesday, 14:30-16:00 - Graham Hills GH614, Level 6

Dynamical Models in Sustainable Development III

Stream: Dynamical Models in Sustainable Development
Invited session
Chair: *Doris Behrens*

1 - Consideration of inhomogeneity in activated sludge bioreactors for the bioremediation of water resources

Maria Crespo Moya, Benjamin Ivorra, Angel Manuel Ramos, Alain Rapaport

In this talk, we study optimal and suboptimal control strategies for the treatment of a polluted water resource by using aside a continuous bioreactor. The control consists in choosing the inlet volumetric flow rate for filling the bioreactor with contaminated water from a considered resource (lake, reservoir, water-table...). We tackle an optimization problem which aims to minimize the time needed to reach a prescribed minimal value of contamination in the resource by choosing the input flow. Furthermore, we study the influence of inhomogeneities of concentrations in the bioreactor, considering a system based on partial differential equations which describe its behavior. We show that applying the optimal feedback derived for perfectly mixed bioreactor does not allow to reach the target with small diffusion parameters as it drives the bioreactor to washout (the bioreactor equilibrium with no biomass). In this case, a suboptimal feedback (with which the target is reached at finite time) is obtained with the help of an Hybrid Genetic Algorithm. In addition, we consider that the fluid flow velocity of the water entering into the bioreactor follows either an uniform or an nonuniform profile, showing that the optimal volumetric flow rates obtained with the uniform profile are not optimal if the profile is nonuniform, even when high diffusion coefficients are considered in the model.

2 - Environmental and security challenges of electricity markets

Sebastian Zapata, Carlos Jaime Franco, Isaac Dyner Rezonzew

One of the major concerns of policy makers in the power industry is both security of supply and low electricity cost to consumers, especially nowadays with a larger share of renewable energies worldwide (e.g. solar PV and wind energy). In this context, system reliability might be in conflict with economic efficiency and/or environmental protection, thus increasing problem complexity.

This paper uses system dynamics modelling to analyse policy that aims at increasing the penetration of renewables and how these energies affect system reliability. In this context, and given multiple uncertainties that include the evolution of technology and its capital cost, scenario analysis has been considered for investigating different, extreme, though plausible futures. Simulations, under extreme scenarios, help in assessing the effects of policy incentives to solar PV and wind technologies in current electricity markets. This paper concludes that for

the Colombian case, the potential of renewable energies seems promising, given the fast learning curves of these technologies and their particular complementarity.

3 - Modeling the upgrading of domestic refrigerators in Colombia

Jenny Rocio Rios Martinez, Yris Olaya Morales

In Colombia, according to the Survey of Life Quality from 2003 to 2012, conducted by National Administrative Department of Statistics, almost 80% of households have a refrigerator-freezer. Refrigerators-freezers account for 20 to 50% of energy consumption in low income households. As service life of refrigerators in Colombia ranges from 15 to 25 years, the average efficiency of refrigerator stock is still low despite efforts to promote energy efficient appliances. We develop a simulation model using System Dynamics methodology to analyze and compare different scenarios for incentive the replacement of refrigerators. The model combines a discrete choice model that determines the consumer's probability of replacing inefficient refrigerators and a dynamic model for the refrigerator stock. The model is able to simulate the impact of different energy efficiency policies for promoting the adoption of energy efficient refrigerators. We simulate five alternative policies and compare the simulation results with the current policy (Business as usual). Three of the policies provide financial incentives, from eliminating value added taxes to subsidizing appliances, and we test an information policy that complements the labeling program. Simulation results show that the simultaneous application of financial and information programs is more effective than financial or information-only programs for promoting efficient refrigerator adoption in households.

4 - Sustainable Urban Development as a Dynamic Economic System: An Optimal Dynamic Control Approach

Doris Behrens, Birgit Bednar-Friedl, Dieter Grass, Olivia Koland, Ulrike Leopold-Wildburger

By 2050 urban areas are presumed to be the living environment for 86 percent of the population in the more developed regions. Now and in the future the efficient design of urban centers to remain or become livable places for an increasing population, both in terms of economic opportunities and environmental quality, constitutes a significant management problem for any urban planner. We seek to apply predator-prey modeling to shed light on the demanding task to efficiently manage urban economic development (UED). We focus on population density and environmental pollution as critical abundances for UED. Population density is being modeled as a prey-type variable, since even at zero pollution it would not exhibit more than logistic growth behavior. Pollution is regarded as being a predator-type variable, since it would (nearly) disappear in absence of people driving cars and/or needing housing facilities; pollution increases with the demand for mobility and housing services. By applying optimal control theory to our predator-prey type model of UED we seek to understand the effect of management decisions like implementing or delaying pollution control or behavioral measures on both residential density and the level of environmental pollution. The analysis is performed for Graz, Austria, which constitutes a prototypical example of a(n attractive) small urban center suffering from high particulate matter emissions. Numerical solutions are derived by using the OCMat software.

■ WD-54

Wednesday, 14:30-16:00 - Graham Hills GH617, Level 6

Optimal Control Applications

Stream: Optimal Control
Invited session
Chair: *Gernot Tragler*

1 - Zeno Points in Multi-stage Models
Andrea Seidl

The inclusion of multi-stage methods can lead to phenomena which cannot occur in a comparable single-stage optimal control framework. If a decision maker can optimally decide whether and when to switch between two different regimes, points can exist, where it is optimal to switch back and forth between the stages with switching time zero if there are no switching costs. This means that at this point there is an infinite number of switches in a finite amount of time. This phenomenon is known as Zeno point.

Within a simple capital accumulation we study the occurence and implications of Zeno points. We conduct a bifurcation analysis and show that the inclusion of switching costs can lead to the occurence of a periodic solution originating from the Zeno point within a one-state model.

2 - Endogenous growth and structural change through vertical and horizontal innovations
Anton Bondarev, Alfred Greiner

This paper combines horizontal and vertical innovations to generate an endogenous growth model allowing for structural change as an endogenous phenomenon. Older technologies are continuously replaced by newer ones due to creative destruction and new technologies appear as a result of horizontal innovations and due to the consumers' preference for variety. We assume fixed operational costs for the manufacturing sector and an endogenously defined patent price for every new technology. Every industry is profitable only for a limited period of time, making the effective time of existence of the technology endogenous and finite. We find that in such an economy endogenous structural change is the source of ongoing economic growth. Further, the range of existing sectors stays constant as well as growth rates as long as the technologies are symmetric.

3 - Optimal Renewable Energy Generation when Supply Fluctuates Seasonally
Gernot Tragler, Elke Moser

One of the biggest challenges along the path towards a more sustainable energy supply is to find a low-carbon energy technology that simultaneously guarantees energy security. However, in contrast to fossil resources, renewable ones strongly fluctuate and are often hard to predict. Consequently, the interplay of generated surpluses and shortfalls as well as limited storage possibilities complicate proper scheduling of renewable energy generation. Moreover, renewable energy technology comes along with high investment costs that strongly restrict their profitability. While these high costs decline after some time in operation due to increasing experience and know-how, the planning horizon typically is too short to take these learning effects into account, implying that investments for renewable energy technologies are often postponed into the future, which strongly restricts the scope of renewable energy generation. We address this issue with optimal control models describing the energy planning decision of a small country optimizing a portfolio consisting of fossil and renewable energy to cover the country's energy demand. While fossil energy is assumed to be constantly available, renewable energy is fluctuating seasonally. To investigate the differences in the outcome depending on whether the mentioned learning effects are included in the decision process or not, different model approaches are presented.

4 - Joint Pricing and Inventory Control with a Price-Dependent Shortage Cost
Qingqing Wu, Peng Hu

In the market with demand uncertainty, shortage can result in the loss of good will for potential consumers, where the loss is related to the selling price. Because price measures the value of this product for consumers who attempt to purchase, a higher selling price can cause more loss of will to customers. Based on this, this paper addresses the joint pricing and inventory replenishment strategies with a price-dependent shortage penalty cost under the classic newsvendor setting. It characterizes the structure of the optimal combined pricing and inventory strategies that maximizing the expected profit, proves the monotonicity of the optimal price in term of the marginal effect of the shortage in price under the general setting, and provides a sufficient condition of the monotonicity of optimal order quantity. Finally, a numerical study is conducted so as to illustrate the monotonicity of optimal order in general and the applicability of its sufficient condition.

■ WD-55

Wednesday, 14:30-16:00 - Graham Hills GH626, Level 6

Simulation in Management Accounting and Management Control II

Stream: Simulation in Management Accounting and Management Control
Invited session
Chair: *Arno Karrer*

1 - A Bayesian decision making approach for product transactions with multiple consumers
María Jesús Rufo Bazaga, Jacinto Martín, Carlos Javier Pérez Sánchez

An important issue in industrial and commercial applications is the product quality demostration. Product commercialization is the main objective. This work presents a Bayesian sequential negotiation model among multiple parties (a manufacturer and several consumers) on two issues (price and product quality). Observe that the product quality depends on the problem at hand. A product sample for testing is considered and no mediator's presence is required. Thus, the manufacturer directly interacts with the consumers. In addition, each consumer does not have any knowledge about the preferences and judgements of the remaining ones. This lead to a decision problem that is solved under the manufacturer viewpoint. The main aim for him/her will be that at least one consumer accepts the product batch based on either product price or product price and quality. A simulation-based approach is implemented to find the optimal solution, i.e., the optimal price and sample size that the manufacturer should offer the consumer is obtained. Finally, an application is presented to show that this technique can be easily applied in practice.

2 - Transfer pricing — heterogeneous agents and learning effects
Arno Karrer

In this paper we analyze the impact of heterogeneous agents and learning effects on the consolidated profit and transfer price. An agent-based simulation is employed to show potential results implied by learning and interaction effects between negotiating profit centers. In particular, intra-company profit centers can choose to trade with each other or with independent parties on an external market, which is technologically as well as demand independent. The profit centers have heterogeneous information about this external market and heterogeneous but time-continuous behaviour in negotiations with each other. Potential results show how learning and interaction effects may affect the decision making process and the consolidated profit. Furthermore, we investigate whether long term learning effects cause quantity decisions which are optimal with respect to the firm's overall objective.

■ WD-60

Wednesday, 14:30-16:00 - Graham Hills GH813, Level 8

Simulation and Software Challenges

Stream: Disaster Risk Management
Invited session
Chair: *Stefan Droste*

1 - The impact of coordination on the effectiveness of last mile relief distribution
Priyanka Roy, Chris Owen, Pavel Albores, Christopher Brewster

Last mile relief distribution is the final stage of humanitarian logistics. It refers to the supply of relief items from local distribution centers to the disaster affected people (Balcik et al., 2008). In the last mile relief distribution literature, researchers have focused on the use of optimisation techniques for determining the exact optimal solution (Liberatore et al., 2014), but there is a need to include behavioural factors with those optimisation techniques in order to obtain better predictive results. This paper will explain how improving the coordination factor increases the effectiveness of the last mile relief distribution process. There are two stages of methodology used to achieve the goal: Interviews: The authors conducted interviews with the Indian Government and with South Asian NGOs to identify the critical factors for final relief distribution. After thematic and content analysis of the interviews and the reports, the authors found some behavioural factors which affect the final relief distribution. Model building: Last mile relief distribution in India follows a specific framework described in the Indian Government disaster management handbook. We modelled this framework using agent based simulation and investigated the impact of coordination on effectiveness. We define effectiveness as the speed and accuracy with which aid is delivered to affected people. We tested through simulation modelling whether coordination improves effectiveness.

2 - A Graphical User Interface for Managing Disaster Operations
Stefan Droste

The joint project "Decision Support System for Large-Scale Evacuation Logistics" is developing a system helping firefighters or policemen to plan, optimize and evaluate different evacuation scenarios. Funded by the French ANR and the German BMBF, it is a cooperation between French and German partners from science and industry. In this talk we present its graphical user interface that allows the end user to setup different evacuation scenarios, compute optimized evacuation plans, analyze them with respect to different key figures and refine the scenarios according to these results.

The main focus of the user interface lies on enabling the user to do all the above tasks in one unified environment: the main window contains a freely zoomable map, into which a street network can be imported from OSM data. Editing this network allows to define bus depots, gathering points, and shelters. Specialized algorithms compute optimized evacuation plans bringing all evacuees to shelters by bus transfer or individual traffic. These solutions are visualized on the map, busy streets are highlighted, and the bus schedule is shown on a Gantt chart, allowing the user to focus on the spatial or temporal points of interest easily. A spiderweb chart simplifies choosing between different evacuation plans with respect to a number of criteria.

■ WD-61

Wednesday, 14:30-16:00 - Graham Hills GH816, Level 8

Dynamic Vehicle Routing

Stream: Routing II - Emerging Applications
Invited session
Chair: *Djamila Ouelhadj*

1 - A real-world application of a dynamic dial-a-ride problem for non-emergency ambulance services in Austria
Marco Oberscheider, Patrick Hirsch

The presentation deals with the implementation of a decision support system (DSS) that contains a module for optimizing the patient transports of the Red Cross of Lower Austria. The optimization is done by a variant of Adaptive Large Neighborhood Search. As only parts of the requests are known at the beginning of the day, while the rest of them is revealed over time, continuous re-optimization is crucial to cope with the dynamic nature of the underlying dial-a-ride problem. It is specified by multiple depots with a varying number of heterogeneous vehicles. Vehicles start at depots on their first requested service and have to return after a specified shift length. Moreover, mandatory breaks have to be taken. With vehicles of type A up to three ambulant patients can be served, while vehicles of type B are able to transport a maximum of two patients with different types of mobility (ambulant, recumbent, wheelchair). Time windows are given at pickup locations and the extension of the ride time of one patient, due to the service of additional patients, is restricted. The duration for servicing patients at pickup or delivery nodes depends on the type of mobility, the vehicle type, the combination of patients and the pickup or delivery locations. Daily problem instances with up to 848 requests are tested, while the solution of the dynamic variant is compared to its static counterpart and the manual schedule. The solutions reveal the potential of the implemented DSS.

2 - Dynamic maintenance scheduling and routing for offshore wind farms
Djamila Ouelhadj, Chandra Irawan, Dylan Jones

We propose a dynamic maintenance scheduling and routing model for offshore wind farms based on the set-partitioning technique. The model finds the optimal schedule for maintenance of the turbines and the optimal routes for the vessels to service the turbines. The main objective of the model is to minimise the total travel, power loss, and crew costs. The type of vessels considered in the model is Crew Transfer Vessels.The model also takes into account multiple periods, multiple Operation & Maintenance bases, and multiple wind farms. We develop an algorithm which incorporates a mixed integer linear programming model for generating feasible vessel routes and maintenance schedules considering several constraints such as weather condition, the availability of vessels, and the availability of crews. The algorithm finds

sets of turbines that are feasible to be maintained in a time period and determines the routing for vessels to visit those turbines. We have also developed an integer linear programming model to select the optimal maintenance schedule and route from the feasible ones. The computational experiments show that the proposed optimisation models and solution methods produce very promising results.

3 - A Biased Randomised Clark and Wrights Savings Heuristic for the Time dependent Pollution Routing Problem
Hassana Abdullahi, Djamila Ouelhadj, Dylan Jones, Angel A. Juan

The problem considered in this paper is the Time dependent Pollution Routing Problem (TDPRP) which deals with the problem of routing a fleet of vehicles to serve a set of customers with known demand and set time windows while considering the speed of each vehicle on each arc. We propose an integer linear programming model and the Biased Randomized Clarke and Wrights Savings Heuristic (BRCWSH) to solve the problem, explicitly taking into account traffic congestion. Using benchmark instances, computational experiments will be conducted to evaluate the performance of the proposed formulation and the solution quality generated using BRCWSH.

4 - A Sim-heuristic algorithm for Robust Vehicle Routing Problems with Stochastic Demand
Abdulwahab Almutairi, Djamila Ouelhadj, Dylan Jones, Banafsheh Khosravi, Angel A. Juan

In this paper we consider the Vehicle Routing Problem with Stochastic Demand (VRPSD) in which customers' demands are stochastic. We propose to model and solve the VRPSD by developing a robust optimisation model with a sim-heuristic solution method that allow us to minimise the transportation cost while satisfying all demands in a given bounded uncertainty set. The sim-heuristic algorithm combines Monte-Carlo Simulation with classical Clarke and Wright heuristic in order to efficiently solve the VRPSD combinatorial optimisation problem. Computational experiments have been conducted on benchmark problems from the literature. The results validate the efficiency of the robust optimisation model with the sim-heuristic solution method in generating very good quality solutions compared to those in the literature.

■ WD-62

Wednesday, 14:30-16:00 - Livingstone LT203, Level 2

Operations Research 11

Stream: Operations Research, other
Contributed session
Chair: *M. Navabi*

1 - Lambert's Problem Solver for Interplanetary Trajectory Optimisation
M. Navabi, Parvin Keyvani

In this paper we present an optimal transition interplanetary trajectory using the Lambert's problem. Selected method for Lambert's problem calculates the solar system objects state vectors precisely. At first changes in the true anomaly, the minimum transfer time and maximum allowable revolutions around the central body should be calculated. Lambert's problem solver algorithm presented in this paper is based on Prussing and Ochoa. These solutions may involve elliptical orbits and also, if the transfer time is too short, it is a hyperbolic transfer. The accuracy of the results obtained by the solver makes it a good tool to be used for preliminary design.

2 - Optimal flight control of damaged Aircraft
Parastoo Roosgard, M. Navabi

Loss of control during the flight can cause control system performance deterioration. That's because aircraft dynamics are severely affected by the failures and damages and if the corrective command signals are not supplied immediately, damages will lead aircraft to instability and catastrophic consequences. Therefore, fault-tolerant flight control system design recently has became the subject of many researches to enhance the flight safety and ensure that damaged aircraft can be stabilized and controlled at all times in the presence of unforeseen and adverse flight conditions. The overall objective with this paper is to

evaluate a method for designing a nonlinear fault-tolerant flight controller with concern in minimizing the design effort. The method is called nonlinear optimal control which is based on State-dependent Riccati Equation (SDRE). A few types of damage scenarios including loss of thrust and actuator malfunctions is considered and both linear and nonlinear control methods is carried out and compared to show the effectiveness and preference of the proposed nonlinear controller. The simulations are implemented on two nonlinear transport aircraft models and the results are discussed.

3 - Modelling Dynamic Redemption and Default Risk for LBO Evaluation: A Boundary Crossing Approach

Maximilian Schreiter, Alexander Lahmann

In this paper, we develop a model that allows evaluating the financial effects of leveraged buyouts (LBOs) from the perspective of the investor. We provide explicit form solutions for all payoffs from acquisition to exit and therefore feature the determination of net present value (NPV) and internal rate of return (IRR). The model is based on a boundary crossing approach where the default of the target firm is represented as a lower piecewise linear barrier. Those default barriers either consist of debt repayment and interest expenses or are contractually-fixed by covenants like debt-to-EBITDA. Our approach features the typical LBO debt repayment schedules: fixed and cash sweep. Furthermore, the model captures all drivers of performance and leverage identified by empirical studies: firm-specific ones like profitability, cash flow growth, volatility, and liquidation value as well as external ones like credit risk spreads and pricing discounts for debt overhang. Overall, the paper provides a solid model for how to plan and evaluate LBOs, as well as for empirical testing of those.

■ WD-67

Wednesday, 14:30-16:00 - Livingstone LT210, Level 2

Graphs and Networks

Stream: Graph Searching
Invited session
Chair: *Nancy Clarke*

1 - Domination triangle, irredundance triangle and 1-triangle graphs

Yury Kartynnik, Pavel Irzhavski, Yury Orlovich

A vertex subset in a graph is called a neighborhood set if the subgraphs induced by the closed neighbourhoods of the vertices in this subset cover the graph. The class of triangle graphs is defined by every maximal independent set being a neighbourhood set. We introduce, characterize and study some similarly defined subclasses of triangle graphs, namely domination triangle, irredundance triangle, and 1-triangle graphs. These classes are used to establish some hardness and inapproximability results for independence- and domination-related parameters, including variations of neighbourhood numbers.

2 - Threshold Weighted - Minimum Dominating Set (TW-MDS): An optimization technique for analyzing complex economic networks

Georgios Sarantitis, Theophilos Papadimitriou, Periklis Gogas

The Minimum Dominating Set (MDS) is a well-known optimization technique within the context of Graph Theory. It is used in data mining applications, wireless communication networks' configuration, biological networks' analysis, etc. We advance this methodology and render it appropriate for the analysis of complex economic networks by adding two important steps. The first step is a thresholding procedure that eliminates all low correlation edges and allows us to work only highly informative data. The other addition is the assignment of weights to the nodes according to their relevant importance in the network. Since the MDS identification procedure essentially solves an integer programming problem that minimizes an objective function, the most important nodes (according to a selected attribute) are assigned inversely low weights. This forces the algorithm to select the most important node as a MDS element among a group of possible MDS nodes. Thus, the Threshold Weighted — Minimum Dominating Set (TW-MDS) is an extension of the classic MDS that it is more appropriate for the analysis of complex economic systems and the extraction of consistent and meaningful information about the network's

topology in a static or dynamic analysis. We display a macroeconomic example where we compare the merits of the TW-MDS over the classic MDS. We conclude that the TW-MDS is superior as it yields more meaningful and consistent results for the purposes of our analysis.

3 - Optimal edge deletion for limiting the spread of contagion

Jessica Enright

Real-world biological or information pathogens can be modelled as contagion spreading on contact graphs between agents. The control of contagion on graphs is therefore an area of both theoretical interest and critical practical importance. We describe our work on optimal link deletion in order to minimise potential outbreak size, with motivation and testing in an agricultural livestock disease setting.

In an undirected graph with one initial contagion incursion, the size of the largest connected component is an upper bound on the maximum size of an outbreak. We therefore investigate minimum link deletion to limit the maximum connected component size in the resulting graph. We present our initial efforts: a polynomial-time algorithm for this problem when the underlying contact graph is a tree, an assessment of the potential for a heuristic approach, and examples of applications of these methods to graphs derived from livestock movements in Great Britain.

4 - Dynamic Graph Colouring Problems

Bradley Hardy, Rhyd Lewis, Jonathan Thompson

The static graph colouring problem (GCP) is concerned with colouring the vertices of a graph such that no adjacent vertices have the same colour and the number of colours used is minimised. By considering the vertices and edges of a graph as abstract representations of objects and constraints, methods for solving the static GCP have been applied to many real world problems including event scheduling and frequency assignment.

The GCP can be extended to a dynamic version (DGCP) by allowing a graph to change at given time steps. These changes can be based on both the vertex set and the edge set, representing changes to the size or the constraints of a problem. One of the main goals of researching the DGCP is to find ways in which solutions to previous problems (represented by similar graphs) can be recycled and adapted to save time and resources. By doing so, it is hoped that improved solutions can also be attained.

Many heuristic methods have been developed and applied to the static GCP as it is known to be NP-hard. In a similar fashion, this research aims to extend some of these methods for the DGCP whilst considering the robustness of solutions to future change. The aim is to find solutions which are not only feasible for the current time step of a problem but will also have a high probability of being feasible for future time steps.

■ WD-78

Wednesday, 14:30-16:00 - Architecture AR201, Level 2

Societal Complexity and Sustainable Development

Stream: Methodology of Societal Complexity
Invited session
Chair: *Cathal Brugha*
Chair: *Dorien DeTombe*

1 - Taking account of the time in economic valuation studies

Jerzy Sleszynski

Thanks to the new and very dynamic branch of environmental economics named economic valuation a lot of intriguing results was worked out and published enlarging our knowledge and understanding of non-market goods and services. Applying economic valuation methods, first of all direct valuation methods based upon questionnaire techniques, researchers measured consumers' willingness to pay for many goods which are not present on the regular markets and do not have price. This category includes also environmental goods and other benefits granted because of the biological production of small and large ecosystems.

Unfortunately, time factor used to be intentionally marginalized in many valuation studies. This is why this article concentrates on a

passive role and also on an active role played by time factor in economic valuation. The paper asks for a clear information about the date of implementation of valuation method and also for a more advanced representation of time in valuation research on natural capital. The paper proposes a brief analysis of time factor and discount rate applied to Cost-Benefit-Analysis. In addition, the paper enumerates facts and difficulties connected with adaptation of time factor to the assessment of benefits resulting from the functioning of ecosystems.

2 - Societal Complexity and Legal Problem Solving
Antoinette Muntjewerff

There are major real life problems in our society. Problems as poverty, violence against women and girls, war, terrorism, credit crisis, healthcare, sustainable development, cyber space and many more. Citizens, governments, legal practitioners and legal scientists overstate law as a means to handle these real life problems. What is the role of law in handling real life problems? In this paper we analyze legal problem solving, legal problems and legal solutions. We relate our findings to the theory of the methodology of societal complexity (DeTombe, 2015, 1994) to see what role law can play in handling real life problems.

Wednesday, 16:30-17:45

■ WE-03
Wednesday, 16:30-17:45 - TIC Auditorium A, Level 2

Closing Session

Stream: Opening and Closing Session
Invited session
Chair: *Valerie Belton*
Chair: *Tim Bedford*

1 - Closing Session
Valerie Belton, Tim Bedford

Thank you for participating in EURO-2015 and for having shared knowledge and ideas with colleagues and practitioners.

Agenda: 1. Awards 2. Calls 3. Special Issues 4. Farewell Addresses

Airport Operations and Airline Scheduling

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Daniel Karapetyan
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Track(s): 49

Algorithms and Computational Optimization

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Haldun Sural
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Track(s): 31

Allocation Problems in Game Theory and Some Problems on Inventory and Logistics Situations

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Track(s): 28

Analytic Hierarchy/Network Process

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Applications of Dynamical Models

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Track(s): 53

Applications of Operations Research in Education

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Track(s): 36

Behavioural Operational Research

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Track(s): 77

Biomass-Based Supply Chains

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Track(s): 17

Boolean and Pseudo-Boolean Optimization

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Track(s): 72

Business Analytics and Intelligent Optimization

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Track(s): 69

Case Studies in OR / Analytics

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Track(s): 42

Combinatorial Optimization

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Track(s): 67

Community OR

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Computational Biology, Bioinformatics and Medicine

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Computational Statistics

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Track(s): 69

Computing

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Container Terminals

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Track(s): 50

Continuous Multiobjective Optimization and Robustness

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Track(s): 25

Continuous Optimization (contributed)

Track(s): 28

Control Theory & System Dynamics (contributed)

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Track(s): 54

Convex Optimization

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Track(s): 28

Convex, Semi-Infinite and Semidefinite Optimization

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Track(s): 26

Customer Based Services: Personalization, Interaction and Strategies

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Track(s): 38

Cutting and Packing

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Track(s): 15

Data Analysis for Emerging Applications

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Track(s): 29

Data Mining in Early Warning Systems

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Track(s): 29

Data Mining in Finance and Commodities

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Track(s): 55

Data Science for Optimisation

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Track(s): 70

DEA and Performance Measurement

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Track(s): 35

Decision Making Modeling and Risk Assessment in the Financial Sector

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Track(s): 54

Decision Processes

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Track(s): 39

Decision Support Systems

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Track(s): 39

Defence and Security Applications

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Track(s): 43

Demand and Supply in Retail and Consumer Goods

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Track(s): 4

Disaster Risk Management

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Track(s): 60

Discrete and Global Optimization

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Track(s): 72

Dynamic Models in Game Theory

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Track(s): 78

Dynamic Programming

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Track(s): 61

Dynamical Models in Sustainable Development

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Track(s): 53

Dynamical Systems and Mathematical Modelling in OR

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Track(s): 53

Education Policy

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Track(s): 36

Emerging Applications in Game Theory and Management

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Track(s): 27

Emerging Applications in Portfolio Selection and Management Science

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Track(s): 32

Emerging Applications of OR in Economics

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Track(s): 29

Emerging OR Applications on Cloud Computing

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Track(s): 34

Emerging Research and Applications of OR in Understanding Satellite, Climate, Weather and Earth Data

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Energy Market/System Modeling

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Track(s): 18

Energy/Environment and Climate (contributed)

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Track(s): 35

Engineering Optimization

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Track(s): 7

Environmental Sustainability in Supply Chains

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Track(s): 25

EURO Awards and Journals

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Track(s): 2 3

Experimental Perspectives and Challenges in Management Accounting and Management Control

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Financial and Commodities Modeling

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Financial Mathematics and OR

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Forecasting & Time Series Prediction

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Fuzzy Decision Support Systems, Soft Computing, Neural Network

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Fuzzy Optimization - Systems, Networks and Applications

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Game Theory and Social Networks

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Game Theory, Solutions and Structures

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Graphs and Networks

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Humanitarian Applications

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IBM Research Applications

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Information and Intelligent Systems

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Location, Logistics, Transportation (contributed)

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Long Term Financial Decisions

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Long Term Planning in Energy, Environment and Climate

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Lot Sizing, Lot Scheduling and Related Problems

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Methodology of Societal Complexity

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Mixed-Integer Nonlinear Programming

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Multiobjective Optimization - Methods and Applications

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Multiobjective Optimization: Modelling and Algorithms

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Multiple Criteria Decision Aiding

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Nonconvex Programming: Local and Global Approaches

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Nonsmooth Optimization

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Operational Research and Quantitative Models in Banking

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Operational Research in Financial and Management Accounting

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Optimal Control

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Optimization

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Optimization for Sustainable Development

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Optimization of Public Transport

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OR and Climate Change

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OR and Ethics

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Practical Operational Research in Healthcare

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Production and Operations Management

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Production and the Link with Supply Chains

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Project Management and Scheduling

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Quality and Performance Measurement in Humanitarian Relief Chains

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Realistic Production Scheduling

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Recent Advances in Dynamics of Variational Inequalities and Equilibrum Problems

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Revenue Management

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Robust Optimization

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Routing II - Emerging Applications

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Scheduling in Healthcare

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Scheduling Theory and Applications

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Scheduling with Resource Constraints

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Simulation in Health Care

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Simulation in Management Accounting and Management Control

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Stochastic Modeling

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Stochastic Modeling and Simulation in Engineering, Management and Science

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Stochastic Models in Healthcare

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Stochastic Models in Renewably Generated Electricity

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Supply Network Risk and Resilience

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Sustainable Living: Cognitive, Social, Economical, Ecological and World View

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Sustainable Supply Chains

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System Dynamics Modeling and Simulation

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Vector and Set-Valued Optimization

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