UNIVERSITI PUTRA MALAYSIA

SCHEDULING DYNAMIC CELLULAR MANUFACTURING SYSTEMS IN THE PRESENCE OF COST UNCERTAINTY USING HEURISTIC METHOD

AIDIN DELGOSHAEI

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By

AIDIN DELGOSHAEI

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirements for the Degree of Doctor of Philosophy

January 2016

DEDICATION

I Sincerely dedicate all my efforts to my beloved parents who support me in every moments of my life.

Abstract of thesis presented to the senate of Universiti Putra Malaysia in fulfillment of requirement of the Degree of Doctor of Philosophy

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Chair : Mohd Khairol Anuar Mohd Ariffin, PhD
Faculty : Engineering

Nowadays in production rivalry world, designing appropriate layouts and locating machines is an important step in lean production which can increase the performance of a manufacturing system. Cellular Manufacturing Systems covers a wide range of industries. Cost uncertainty which can happen as a result of market changes and inflation rate, is a big concern in scheduling cellular systems as they may impose financial harms to a manufacturing system. Initial investigation in the literature of the CMS studies reveals that the issue uncertain cost in CMS is less developed. It is assumed that a strong production planning can smooth the consequences of uncertain costs in CMS. In this regard, 4 mathematical programming models are developed for forming cells and scheduling the materials on appropriate machines while the system costs are considered uncertain. Since the proposed models (like similar models in the literature) are likely to fall into local optimum points, a Branch and Bound based heuristic, a hybrid Simulated Annealing and Genetic algorithm, a hybrid Tabu search and Simulated Annealing, a hybrid Genetic algorithm and Simulated Annealing, a hybrid Ant Colony Optimization and Simulated Annealing and a hybrid Multi-layer Perceptron and Simulated Annealing algorithms are developed. Then, design of experiments is used to examine the sensitivity of the parameters of each solving algorithm using Taguchi method. Afterward, the proposed solving methods are verified using 17 data sets from the literature and results are analyzed. Results show that during the part-routing process in a normal manufacturing circumstance, nearer set of required machines for producing a product are employed more than other parallel machines. This phenomenon can cause increasing machine-loads in such cells and may lead to machine-load variation in set of closer machines while other machines are allocated less (or even left idle). It is observed that in 67% of studied cases, inflation rate can strengthen cell load variation. To prevent this event a new method is proposed using the statistical process control terms (SPC) which prevent allocating each machine type more than a dynamic upper limit of average of a machine type inside a cell. Results show that in 96.7% of studied cases, the proposed method can significantly prevent machine over allocating in cellular manufacturing systems. While machine broken comes into account, it is found that machine unreliability can cause increasing machine-load variation and strengthen the system imbalance as well. It is also found that using appropriate preventive maintenance program can cause up to 75% reduction in cell-load variation. Similarly using a proper plan for promoting human resources can

significantly reduce cell load variation (76% of studied cases). After designing a cellular manufacturing system and during constructing period, it is shown that using an appropriate backward method to maximize the Net Present Value of activities can be used as a tool for reducing the financial harms imposed by uncertain costs.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Doktor Falsafah

PENJADUALAN DINAMIK CELLULAR SISTEM PEMBUATAN DENGAN KEHADIRAN KETIDAKTENTUAN KOS MENGGUNAKAN KAEDAH HEURISTIC

Oleh

AIDIN DELGOSHAEI

Januari 2016

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Pada masa kini, dalam persaingan industri pengeluaran rekabentuk susun atur yang sesuai dan mesin pengesan adalah satu langkah penting dalam pengeluaran tanpa lemak yang boleh meningkatkan prestasi sistem pembuatan. Sistem Pembuatan Selular meliputi pelbagai industri disamping kos yang tidak menentu yang boleh berlaku akibat daripada perubahan pasaran dan kadar inflasi. Hal ini membimbangkan dalam penjadualan sistem selular kerana perkara ini boleh mengakibatkan kemudaratan kewangan kepada perindustrian. Siasatan awal dalam kajian Sistem Pembuatan Selular mendedahkan bahawa kos tidak tetap dalam Sistem Pembuatan Selular adalah kurang memuaskan. Perkara ini dianggap bahawa perancangan pengeluaran yang tinggi boleh merugikan akibat kos tidak menentu Sistem Pembuatan Selular. Dalam hal ini, empat model pengaturcaraan matematik dibangunkan untuk membentuk sel-sel dan penjadualan bahan pada mesin yang sesuai sambil kos sistem adalah dianggap tidak menentu.

Model yang dicadangkan seperti model yang sama dalam kajian mempunyai kebarangkalian jatuh ke dalam titik optimum, cawangan dan terikat berasaskan heuristik, penyepuhlindapan hibrid simulasi dan algoritma genetik, carian tabu hibrid dan penyepuhlindapan simulasi, algoritma genetik hibrid dan simulasi penyepuhlindapan, pengoptimuman koloni semut hibrid dan penyepuhlindapan simulasi dan pelbagai lapisan perceptron hibrid dan algoritma penyepuhlindapan simulasi dibangunkan. Rekabentuk eksperimen digunakan untuk memeriksa sensitiviti parameter setiap algoritma dalam menyelesaikan masalah menggunakan kaedah Taguchi. Selain itu, penyelesaian menggunakan 17 set data daripada kajian dan keputusan dianalisis. Keputusan menunjukkan bahawa semasa proses pembuatan biasa, set mesin yang diperlukan untuk menghasilkan produk yang bekerja lebih daripada mesin selari lain. Fenomena ini boleh menyebabkan peningkatan beban mesin dan boleh membawa kepada perubahan beban mesin dalam set mesin berdekatan manakala mesin lain kurang diperlukan.

Menurut kajian, diperhatikan bahawa dalam 67% kadar inflasi boleh menguatkan perubahan beban sel. Untuk mengelakkan kejadian ini, satu kaedah baru dicadangkan menggunakan istilah kawalan proses statistik yang menghalang setiap jenis mesin lebih

daripada had atas yang dinamik purata jenis mesin di dalam sel. Keputusan kajian menunjukkan 96.7% daripada kaedah yang dicadangkan ketara boleh mencegah mesin melebihi had dalam sistem pembuatan selular. Bagi mesin yang rosak, didapati bahawa mesin tidak berfungsi boleh menyebabkan peningkatan perubahan beban mesin dan mengukuhkan ketidakseimbangan sistem juga. Ia juga mendapati bahawa menggunakan program penyelenggaraan yang sesuai boleh menyebabkan pengurangan sehingga 75% dalam variasi sel beban. Begitu juga menggunakan pelan yang betul untuk mempromosikan sumber manusia boleh mengurangkan variasi beban sel 76% daripada kes yang dikaji. Selepas rekabentuk sistem pembuatan selular dan tempoh pembinaan semasa, kajian menunjukkan bahawa dengan menggunakan kaedah ke belakang yang sesuai untuk memaksimumkan nilai bersih boleh digunakan sebagai alat untuk mengurangkan kemudaratan kewangan yang dikenakan oleh kos yang tidak tetap.

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I am grateful to Dr. Hang Tuah Bin Bahrudin and also Dr. Zulkifli Bin Leman for their valuable advices and suggestions that are given during the progression of my study and for their participation in my committee.

I also thank all other faculty members who helped me prepare this thesis.

"I dedicate my greatest love to my parents for their love, faith and support."

I certify that a Thesis Examination Committee has met on 19 January 2016 to conduct the final examination of Aidin Delgoshaei on his thesis entitled "Scheduling Dynamic Cellular Manufacturing Systems in the Presence of Cost Uncertainty Using Heuristic Method" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Doctor of Philosophy.

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Declaration by graduate student

I hereby confirm that:

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This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
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LIST OF ABBREVIATIONS

AB	Allowed Backorder
ACO	Ant Colony Optimization
ALINK	Average Linkage Clustering
ALPHA	Inter-Cellular Cost
ANN	Artificial Neural Networks
AOA	Activity on Arc
AON	Activity on Node
AR	Maximum Available Resource
ART	Adaptive Resonance Theory
B	Training Budget
BBC	Black Box Clustering Algorithm
BC	Backorder Cost
BDF	Block-diagonal Form
BEA	Bond-energy Algorithm
Best-observed-F	Best Observed Function
BETA	Intra-cellular Cost
BFA	Bacteria Foraging Algorithm
BnB	Branch and Bound (Algorithm)
BnBLEP	Branch and Bound with Local Escaping Possibility
BP	Binary Programming
BS	Batch Size
CASE	CASE Clustering Algorithms
CC	Course Cost
CCDCMS	Capacity Constrained Dynamic Cellular Manufacturing Systems
CCDCMS-HR	Capacity Constrained Dynamic Cellular Manufacturing Systems Considering Human Resource
CCDCMS-UM	Capacity Constrained Dynamic Cellular Manufacturing Systems With Unreliable Machines
CDR	Clustering and Data Organization
CF	Cash Flow
CFP	Cell Forming Problem
CL	Cell Size
CLINK	Complete Linkage Clustering
CLLA	Competitive Leaky Learning Algorithm
Cmax	Maximum Completion Time (Refers To Make Span)
CMS	Cellular Manufacturing System
CS	Constant Salary
CSz	Colony Size
D	Product Demand
DCA	Direct Clustering Algorithm
D-CMS	Dynamic Cellular Manufacturing System
DEA	Data Envelopment Analysis
DOE	Design of Experiments
DPA	Dynamic Part Assignment (Method)
DR	Depreciation Rate

Ds.R	Discounted Rate
Du	Duration
e	Epoch
EE	Exceptional Element
EMT	Emergency Maintenance Time
ES	Early Start
ESC	Emergency Services Cost
Eq	Equation
EVR	Evaporating Rate
F	Firing
F.Fcn	Failure Function
FCM	Fuzzy C-means Algorithm
F-iteration	Function Value in Iteration
FLC	Fuzzy Logic Controller
FLC-HGA	Fuzzy Logic Controller And Hybrid of GA
FR	Failure Rate
FSP	Forward Serial Programming
G	Generation
GA	Genetic Algorithm
GATSP	Graphical Asymmetric Traveling Salesman Problem
GDP	Gross Domestic Product
GMDAS	Generalized Mixture Decomposition Algorithmic Scheme
GP	Genetic Programming
GP-SLCA	Genetic Programming and Single Linkage Cluster Analysis
H	Hiring
HRM	Human Resource Management
IP	Integer Programming
IR	Inflation Rate
itr	Iteration
JSC	Jaccard’s Similarity Coefficient
K	Machine Purchasing Cost
KHM	K-Mean Harmonic Clustering Algorithm
KNN	K Nearest Neighbor
LearnParam	Learning Parameter
LEP	Local Escaping Probability
LF	Late Finish
Long.memo	Long Term Memory
MA	Machine Capacity
MCDM	Multi Criteria Decision Making Model
MCIM	Machine Component Incidence Matrix
MG	Machine Group
MIP	Mixed Integer Programming
MJSC	Modified Jaccard’s Similarity Coefficient
MLB-SC	Machine Level Based-Similarity Coefficient
MLP	Multi-layer Perceptron
MP	Mathematical Programming
MRCPSP	Multi-mode Resource Constraint Project Scheduling Problems

MRCPSP-DCF	Multimode Pre-emptive Resource-constrained Scheduling with Discounted Cash Flows
MST	Minimum Spanning Tree Algorithm
Mu	Mutation
MVFCM	Modified Version of Fuzzy C-means Algorithm
NLMIP	Nonlinear Mixed Integer Programming
NOM	Initial Number of Machines
NP-hard	Non-polynomial Hard
NPV	Net Present Value
OC	Operator Capacity
OP	Operation Cost
OPC	Operation Process Chart
OS	Outsourcing Cost
OSGTMA	Operation Sequences Group Technology Machine Assignment Algorithm
P	Predecessor
PCA	Part Coding Analysis
PCM	Possibilistic C-means Algorithm
PerfFcn	Performance Function
PF	Part Family
PL	Preventive List
PMC	Preventive Maintenance Cost
PMP	P-median Problem
pop.size	Population Size
PP	Progress Payment
PPGA	Predator–prey Genetic Algorithm
PSO	Particle Swarm Optimization
PSOKHM	Particle Swarm Optimization with K-Mean Harmonic
PST	Preventive Service Time
QAP	Quadratic Assignment Problem
QDDH	Quadra-directional Decomposition Heuristic
r	Resource Usage of an Activity
R	Neighborhood Radius
RC	Resource Capacity
RC-MPSP	Resource-constrained Multiple Project Scheduling Problem
RCPSP	Resource-constrained Project Scheduling Problem
RCPSP-DCF	Resource constrained Project Scheduling Problem with Discounted Cash Flows
ROC	Rank Order Clustering
S	Setup Cost
SA	Simulated Annealing
SCI	Sub-contractor Capability
SDCWP	Simultaneous Dynamic Cell Formation and Worker Assignment Problem
Sem.coef	Similarity Coefficient
Seucc	Successor
Short.memo	Short Term Memory
SI	Similarity Index

SLINK	Single Linkage Clustering Algorithm
SOM	Self-organizing Map
SR	Skill Rate
SQC	Statistical Quality Control
STD	Standard Deviation
TAU	Initial Level of Pheromone
TB	Training Budget
Tbs	Tabu List Size
TH	Time Horizon
TOPSIS	Technique for Order of Preference by Similarity to Ideal Solution
TQM	Total Quality Management
TR	Training Cost
Tr	Threshold Value
TS	Tabu Search
TSP	Travel Sale Man Problem
UB	Upper Bound
VS	Valley-seeking Clustering Algorithm
W	Wage
WIP	Work-in-process
WLINK	Weighted Linkage Clustering
ZETA	Inspiration Rate
ZODIAC	Zero-one Data Ideal Seed Algorithm for Clustering

CHAPTER 1

INTRODUCTION

1.1 Manufacturing Systems and Lean Production

Nowadays in production rivalry world, it is necessary for every manufacturing systems to plan and control the manufacturing process in details from the ordering and receiving raw material until delivery and after sale services to customers. Food, oil, petrochemical, motor vehicle and tobacco are examples of manufacturing industries. Designing appropriate manufacturing systems is an important part of Lean Manufacturing. Tompkins et al. (2003) reported an estimating of over $250 billion which is spent annually in the United States of America for facility designing, planning and re-planning.

1.1.1 Facility layout

Facility layout is a very important steps in lean production. Generally, scientists classified manufacturing companies to 3 types based on their system design.

a) Flow shop: or multi-product batch plants are employed when all the products in a production line following the same sequence of operations. Ice cream, cookies, lamp and keyboard are good examples of flow shop companies as shown by figure 1.1. Normally assembly line is good for those products which have many similarities in their production process which enables them be produced in one production line. Moreover, due to small changes, the speed of production is usually high and therefore this arrangement is suitable for mass volume production.

Figure 1.1 Icream production line needs a flow shop design (Icecream Production Line. Retrieved at 21/1/2016 from [www.allposters.com/-sp/Ice-Cream-Production-Line)](www.allposters.com/-sp/Ice-Cream-Production-Line)

b) Job Shop: in job shop or multi-purpose batch plants, machines are located in shops based on their functions (cutting, welding, press and painting shops). Products can follow different processing sequences according to their Operational Process Chart (OPC) but not necessarily they visit all the stages. Job shop includes wide range of businesses. Most of the assembly products which contain several parts are produced in companies with job shop design like cutting glass company (whom different types of galsses uses various machines to cut, form or bend), some vehicle parts which needs cutting, pressing, welding and painting as shown by figure 1.2.

Figure 1.2 Functional shops in glass cut company (Bordering, Sekuritting, Punching and Bending) (Arian Shisheh Company. Retrived at 25.05.2013 from www.arianshisheh.com.)

c) Group technology: is defined as an engineering philosophy of recognizing similar parts and grouping them in order to take the advantage of similar product designing and producing.

Figure 1.3 Various stages in a GT company (design department, technical department, part families, scheme of a cell) (Amirnia Company. Retrived at 25.05.2013 from http:/www.amirnia.com)

Figure 1.3 shows Amirnia Company which is considered as a mass producer of various motor vehicle parts. In design department, engineers try to find similarities between products to make product families. They also try to make best machine groups which can meet production requirements of part families based on their needs. Second image of figure 1.3 shows a training course, which is prepared by technical department, for operators. In this stage, lecturer tries to show similarities in detail for operators. Figure 1.3 shows similar parts in part families and last image shows one of the GT shops which are designed based on part family needs.

Cellular manufacturing systems (CMS) as shown by figure 1.4 is considered as effective way of using group technology by defining manufacturing system as a hybrid system of cells linking the advantages of both the jobbing (flexibility) and mass (efficient flow and high production rate) production approaches (Papaioannou and Wilson, 2010).

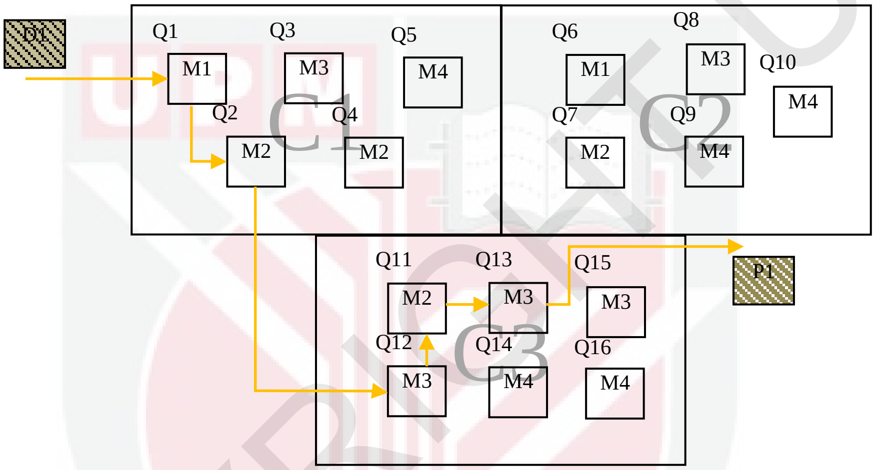

Figure 1.4 A typical layout of a CMS

1.1.2 Choosing Cellular Manufacturing Systems

This research focuses on scheduling cellular manufacturing systems. Reasons for such choosing are summarized below briefly:

a- Cellular Manufacturing Systems covers a wide range of industries Hyer & Wemmerlov (2002). Most of the motor vehicle part manufacturers and electrical home appliances manufacturers use benefits of part family and machine groups in their firms. Machines can be located in cells to rapid up production speed and also reduce set up, production and transportation time and cost as shown by figure 1.3.

b- During last 2 decades, there are many companies that re-structured their system from job shop and flow shop to cellular manufacturing systems Agarwal (2008).

c- Cellular manufacturing has a lot of advantages than other traditional systems. CMS can reduce flow time, flow distance, floor space, inventory, handling, scheduling transactions, and scrap and rework. Moreover, cells lead to simplified, higher validity costing, since the costs of producing items are contained within the cell rather scattered in distance and the passage of reporting time (Papaioannou and Wilson, 2010).

Therefore, in this research, cellular manufacturing systems are considered as the main project envorinment. However, the achievements of this reseach are also useful for job-shop and flow-shop systems.

1.2 Problem statement

Financial aspect is considered as important issue in scheduling cellular manufacturing systems which has direct impact to many areas of manufacturing system studies such as production planning, facility design and utilization. Shanker & Vrat (1998) provided some reasons for considering cost uncertainty in modelling manufacturing systems. They considered cost uncertainities in modelling exceptional elements and bottleneck machines by considering a coefficient in range interval. However, as shown in literature review, the issue of considering uncertain costs in dynamic cellular manufacturing systems is not developed further so far.

Inflation rate is a very important aspect in financial studies which can cause expencess to be changed periodically.
In this research the main aim is to investigate the impacts of inflation rate on scheduling manufacturing systems.

1.2.1 Inflation rate and its importance

Inflation is defined as a sustained increase in the general level of prices for goods and services (according to investopedia website). The same resource provided many reasons why inflation rate must be considered but perhaps the most important is that “the entire economy must absorb repricing costs ("menu costs") as price lists, labels, menus and more have to be updated”.

Results of the recent survey which has been done by trading economics institute shows that that expencess in a society are not fixed and can be varied in short periods (like months and quarters) by inflation rate (figure 1.5).

No.	Country	Calendar			
		04.01.2015	05.01.2015	06.01.2015	07.01.2015
1	Malaysia	1.9	2.8	3.1	3.5
2	Japan	3.2	3.3	1.6	1.5
3	USA	0.9	0.8	1	1.1
4	UK	1	0.9	1.1	1
5	Euro Area	0.4	0.7	0.9	1
6	Germany	0.6	1.09	1.3	1.5
7	France	0.6	0.7	0.9	1.1

Figure 1.5 Monthly inflation rate of some countries (tradingeconomics website. Retrieved at 25/8/2015 from www.tradingeconomics.com)

Such changes in system costs can have effects on many system costs in manufacturing systems like purchasing raw material, production costs, maintenance, emergency services, material transferring, warehousing, human resources. Figure 1.6 shows some of costs in a manufacturing system.

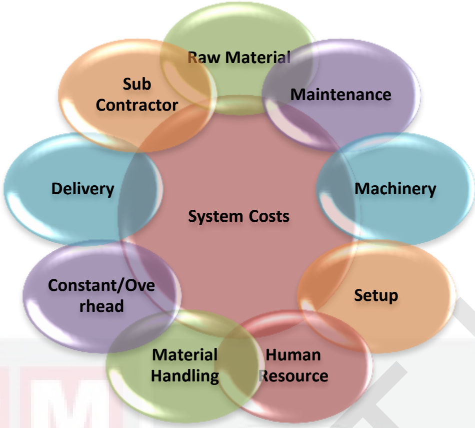

Figure 1.6 Various types of system costs may suffer from financial crisis

Beyond inflation rate, there are also some other reasons for cost uncertainty:
1) Uncertain market changes (wikinvest website. Retrieved at 26.01.2016 from www.wikinvest.com)
2) Currency drop of a country (investopedia website. Retrieved at 21/8/2015 from www.investopedia.com)
3) Global or regional financial crisis (globalissues website. Retrieved at 14.04.2013 from www.globalissues.org)

In this research inflation rate and market changes are considered during the research. Note that the global financial crisis and currency drop is out of the scope of this research and is better to investigate by economic researchers. Moreover, it should be mentioned that dealing with the roots of emerging cost uncertainty in enterprises is out of the scope of this research. Instead, as describe later, our aim is to find ways to reduce the financial harms of such event through happening.

Changing in the costs in short periods may cause difficulties in providing raw material, human resource availability and also can make tremendous effects on costs include transport, production, purchasing, maintenance and even utilization of companies directly or indirectly (figure 1.6).

Hence, it seems necessary to get involve with inflation rate in scheduling manufacturing systems in order to study its negative effects to production systems to set appropriate strategies to smooth the financial harms as much as possible.

1.2.2 Important objectives in studying cellular manufacturing systems

As mentioned in section 1.2.1 manufacturing systems have different types of costs. Although all of them are considered in the models that the models that will be developed in chapter 3, but more attention will be done on 4 objectives which are mentioned below.

- **Material Transferring**

As mentioned in section 1.1, in the year 2003, there are more than $250 billion is spent annually in the United States for facility designing, scheduling and re-scheduling (Tompkins et al., 2003). Of this, a percentage between 20 and 50 belongs to material handling. Using the reported values for GDP that is given in TRADING ECONOMICS® website (contains both production and services expenses); an amount between $3137 and $7842.5 billion can be estimated for United States in year 2012 which is noticeable (according to tradingeconomic website). Moreover, it was also reported that an effective planning can reduce such costs over 10% to 30% that can be estimated an amount between $313.7 and $2352.75 billion can be saved by using appropriate scheduling.

- **Maintenance and emergency services costs**

Besides, Luxhøj et al. (1997) provided a benchmark over maintenance costs in Scandinavian countries (Denmark, Finland, Sweden, & Norway) and United States. They reported an average between 4.9% and 4.8% of annual turnover was dedicated to maintenance activities in Denmark and Finland respectively in 1991. They also reported that in studied cases, 39% of spent times were related to unforeseen repairs. In Norway, 60% of companies believed that maintenance activities were the major cause of production down time. It is also reported that since 1979 maintenance costs in U.S firms have been raised up 10% to 15% per year. By growing up the industries it can be expected more percentage of annually expenses for maintenance issues. As consequence, maintenance issues (both preventive and emergency) are playing key role in reducing costs of manufacturing company.

- **Human resource costs**

Human resources are another factor that play a key role in manufacturing systems. During year 2013, U.S spent $7.0 billion for training and employment (according to usgovernmentspending website). Besides, the jobless rate was 6.7% in U.S in the same year. Since then, during last 2 decades, scientists did their best to define and solve facility problems in various circumstances, conditions and situations to find out new ways to reduce such expenses. Hence, appropriate strategies must be defined to reduce part of the financial harms by using appropriate scheduling.

- **Constructing the manufacturing system**

After designing a manufacturing system, the system must be constructed. Since the uncertain costs can also impose financial harms to manufacturing projects, scheduling manufacturing projects is considered as the last objective of this research.

This research focuses on designing and scheduling of cellular manufacturing systems in dynamic conditions where total costs of system including material transferring, maintenance and services of machines, human resources and also constructing costs are uncertain and supposed to be changed through the time by inflation.

1.3 Hypothesis, questions and objectives

As mentioned in the section 1.2.1 (last paragraph) the aim of this research is to evaluate the impact of cost uncertainty in CMS and the find appropriate ways to reduce its negative effects. Hence, the hypotheses of this study is considered as follow:

1) *First Hypothesis*:

$$\begin{cases} \mathrm{H}_0\text{: Uncertain costs can increase system imbalance} \\ \mathrm{H}_1\text{: Opposite of } H_0 \end{cases}$$

2) *Second Hypothesis*:

$$\begin{cases} \mathrm{H}_0\text{: Using appropriate Scheduling can reduce negative effectsof cost uncertainty} \\ \mathrm{H}_1\text{: Opposite of } H_0 \end{cases}$$

- **Main question:**
  After completing the study, it is expected to answer the main question of this study as:
  "How an appropriate scheduling can reduce the financial harms of uncertain costs in dynamic cellular manufacturing systems?"

- **Sub-Questions:**
  Respecting the topic of the research, the main question can be divided into different subquestions.
  1) To what extent uncertain costs can increase system entropy?
  2) How could managers be able to reduce the system imbalance by modifying material transferring between machines?
  3) How the impact of machine unreliability (service failure) in condition of confronting with uncertain costs event and dynamic customer demands can be reduced?
  4) How using appropriate human resource strategy can reduce the system costs in the presence of cost uncertainty?
  5) How using an appropriate method can increase manufacturing systems' profit in the presence of cost uncertainty?

- **Objectives**

The main aim of this research is to reduce impact of cost uncertainty while scheduling cellular manufacturing systems.

According to the main objective of the research the following objectives can be defined as:
1) To analyze current scheduling methods of dynamic cellular manufacturing systems.
2) To develop appropriate models for designing, scheduling and constructing dyamic cellular manufacturing systems in the presence of cost uncertainty.
3) To propose multi-period scheduling methods for evaluating and reducing impact of cost uncertainty on material transferring, machine unreliability, human resource (hiring, firing and training) and constructing cellular manufacturing systems.
4) To verify and validate the results of the proposed methods in real industries.

The outcomes of this study will help companies to analyse their systems and be ready to make quick response in condition of confronting with cost uncertainty. Such strategies will also help to schedule parts in cells to minimize system imbalance and subsequently system costs in condition of dynamic part demands and uncertain costs.

1.4 Significance of study

1) Evaluating the impact of cost uncertainty and proposing scheduling methods for CMS by considering material handling, machine reliability and human resource costs. (Contribution of the research)
2) New scheduling method(s) will be developed to reduce system costs in the presence of encountering with uncertain costs and dynamic product demands. (Outcomes for applicants)
3) This study will also provide a framework for decision makers in CMS-based companies to set proper decisions while encountering whit the mentioned condition in real industries. (Application in Industry)

1.5 Achievements and novelties

As seen in chapter 2, results of studying the literature show us there are some gaps can be filled regarding to CMS studies. Hence, in this study a frame work will be developed to evaluate impact of cost uncertainty on system performance:
1) Proposing appropriate multi-period scheduling method(s) for reducing impact of cost uncertainty of material transferring.
2) Developing appropriate multi-period scheduling for CMS by considering machine failures in dynamic condition of cost uncertainty.
3) Proposing appropriate multi-period scheduling for CMS by considering human resource factor in dynamic condition of cost uncertainty.
4) Proposing an appropriate method for increasing profits of activity planning in manufacturing projects.

1.6 Scope and limitation of the research

The scope of this study is cellular manufacturing factories in condition of confronting with cost uncertainty as shown by figure 1.7. The detailed scope and limitation of the study based on the date of the study (2012-2015) are as follows:
1) It is considered that financial crisis is probable to occur in many industries through the world.
2) During financial crisis system costs may be uncertain. The product demand can be also dynamic and change from period to period.
3) The negative consequences of cost uncertainty can be smoothed and controlled effectively by appropriate production planning.
4) To verify findings, the approaches and methods in virtual systems must be examined using simulation. Then in the next step, the proposed approaches shall be validated in real companies to verify the results. Malaysia is considered as project environment.

- **Research Domain:**
  This research evaluates the impacts of uncertain costs in cellular manufacturing systems under dynamic condition of product demands and proposes appropriate methods for reducing the harms of cost uncertainty.

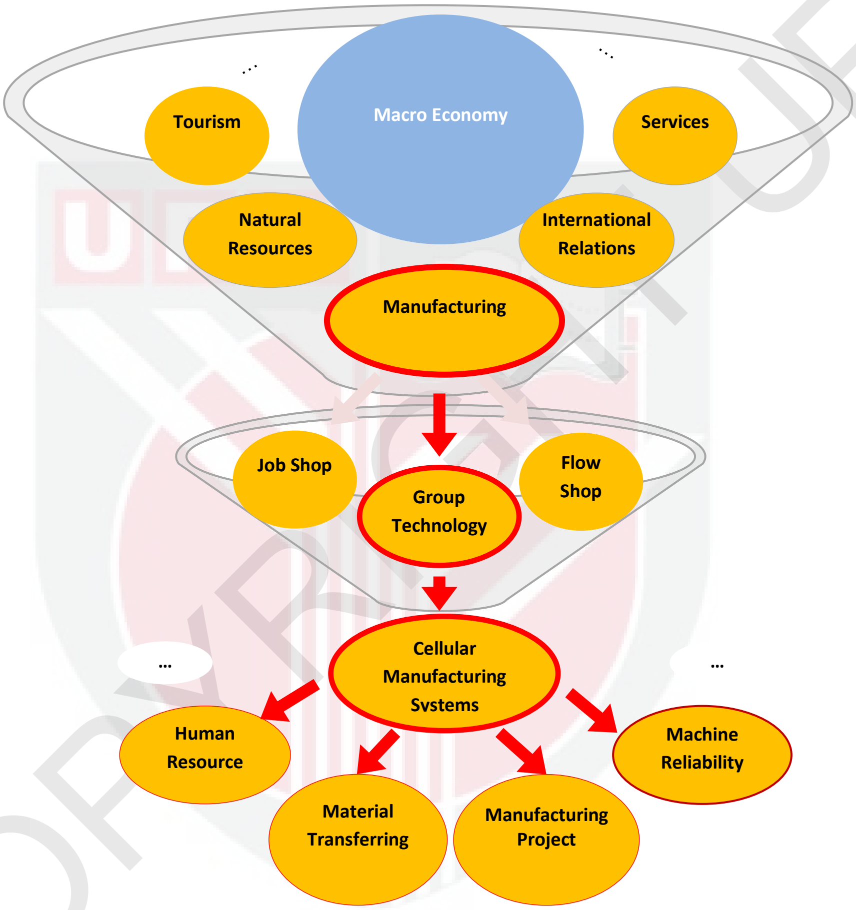

Figure 1.7 A flow diagram for narrowing down and clarifying the scope of the research

REFERENCES

Abbasi, B., Shadrokh, S., & Arkat, J. (2006). Bi-objective resource-constrained project scheduling with robustness and makespan criteria. *Applied Mathematics and Computation, 180*(1), 146-152.

Achuthan, N., & Hardjawidjaja, A. (2001). Project scheduling under time dependent costs–A branch and bound algorithm. *Annals of Operations Research, 108*(1-4), 55-74.

Adenso-Diaz, B., Lozano, S., & Eguía, I. (2005). Part-machine grouping using weighted similarity coefficients. *Computers & industrial engineering, 48*(3), 553-570.

Adil, G. K., & Rajamani, D. (2001). The trade-off between intracell and intercell moves in group technology cell formation. *Journal of Manufacturing Systems, 19*(5), 305-317. doi: 10.1016/S0278-6125(01)89003-8

Agarwal, A. (2008). Partitioning bottleneck work center for cellular manufacturing: An integrated performance and cost model. *International Journal of Production Economics, 111*(2), 635-647.

Agarwal, A., & Sarkis, J. (1998). A review and analysis of comparative performance studies on functional and cellular manufacturing layouts. *Computers & industrial engineering, 34*(1), 77-89.

Ahkioon, S., Bulgak, A., & Bektas, T. (2009). Cellular manufacturing systems design with routing flexibility, machine procurement, production planning and dynamic system reconfiguration. *International Journal of Production Research, 47*(6), 1573-1600. doi: 10.1080/00207540701581809

Al-sultan, K. S. (1997). A hard clustering approach to the part family formation problem. *Production Planning & Control, 8*(3), 231-236.

Alcaraz, J., & Maroto, C. (2001). A robust genetic algorithm for resource allocation in project scheduling. *Annals of Operations Research, 102*(1-4), 83-109.

Alfa, A. S., Chen, M., & Heragu, S. S. (1992). Integrating the grouping and layout problems in cellular manufacturing systems. *Computers & industrial engineering, 23*(1), 55-58. doi: 10.1016/0360-8352(92)90062-O

Angra, S., Sehgal, R., & Samsudeen Noori, Z. (2008). Cellular manufacturing—A time-based analysis to the layout problem. *International Journal of Production Economics, 112*(1), 427-438.

Ariafar, S., Firoozi, Z., & Ismail, N. (2014). A Triangular Stochastic Facility Layout Problem in a Cellular Manufacturing System. Paper presented at the International Conference on Mathematical Sciences and Statistics 2013.

Ariafar, S., & Ismail, N. (2009). An improved algorithm for layout design in cellular manufacturing systems. *Journal of Manufacturing Systems, 28*(4), 132-139. doi: 10.1016/j.jmsy.2010.06.003

Arkat, J., Hosseini, L., & Farahani, M. H. (2011). Minimization of exceptional elements and voids in the cell formation problem using a multi-objective genetic algorithm. *Expert Systems with Applications, 38*(8), 9597-9602.

Aryanezhad, M., Deljoo, V., & Mirzapour Al-e-hashem, S. (2009). Dynamic cell formation and the worker assignment problem: a new model. *The International Journal of Advanced Manufacturing Technology, 41*(3-4), 329-342.

Ashayeri, J., Heuts, R., & Tammel, B. (2005). A modified simple heuristic for the< i> p</i>-median problem, with facilities design applications. *Robotics and Computer-Integrated Manufacturing, 21*(4), 451-464.

Askin, R., & Huang, Y. (1997). Employee training and assignment for facility reconfiguration. *Proceedings of the sixth IERC, Miami, FL*, 426-431.
Askin, R., & Huang, Y. (2001). Forming effective worker teams for cellular manufacturing. *International Journal of Production Research, 39*(11), 2431-2451.
Ayyub, B. M. (2014). *Risk analysis in engineering and economics*: CRC Press.
Baker, R., & Maropoulos, P. G. (2000). Cell design and continuous improvement. *International Journal of Computer Integrated Manufacturing, 13*(6), 522-532.
Balakrishnan, J., & Cheng, C. H. (2005). Dynamic cellular manufacturing under multiperiod planning horizons. *Journal of manufacturing technology management, 16*(5), 516-530.
Ballakur, A., & Steudel, H. J. (1987). A within-cell utilization based heuristic for designing cellular manufacturing systems. *International Journal of Production Research, 25*(5), 639-665.
Ballestín, F., Valls, V., & Quintanilla, S. (2008). Pre-emption in resource-constrained project scheduling. *European Journal of Operational Research, 189*(3), 1136-1152.
Banerjee, I., & Das, P. (2012). Group technology based adaptive cell formation using predator–prey genetic algorithm. *Applied Soft Computing, 12*(1), 559-572.
Baroum, S. M., & Patterson, J. H. (1999). An exact solution procedure for maximizing the net present value of cash flows in a network *Project Scheduling* (pp. 107-134): Springer.
Bartholdi, J. J., & Eisenstein, D. D. (1996). A production line that balances itself. *Operations Research, 44*(1), 21-34.
Basheer, I., & Hajmeer, M. (2000). Artificial neural networks: fundamentals, computing, design, and application. *Journal of microbiological methods, 43*(1), 3-31.
Bazargan-Lari. (1999). Layout designs in cellular manufacturing. *European Journal of Operational Research, 112*(2), 258-272. doi: 10.1016/S0377-2217(98)00164-7
Bazargan-Lari, Kaebernick, H., & Harraf, A. (2000). Cell formation and layout designs in a cellular manufacturing environment a case study. *International Journal of Production Research, 38*(7), 1689-1709.
Berardi, V. L., Zhang, G., & Felix Offodile, O. (1999). A mathematical programming approach to evaluating alternative machine clusters in cellular manufacturing. *International Journal of Production Economics, 58*(3), 253-264.
Boe, W. J., & Cheng, C. H. (1991). A close neighbour algorithm for designing cellular manufacturing systems. *International Journal of Production Research, 29*(10), 2097-2116.
Boulif, M., & Atif, K. (2006). A new branch-&-bound-enhanced genetic algorithm for the manufacturing cell formation problem. *Computers & operations research, 33*(8), 2219-2245.
Buddhakulsomsiri, J., & Kim, D. S. (2006). Properties of multi-mode resource-constrained project scheduling problems with resource vacations and activity splitting. *European Journal of Operational Research, 175*(1), 279-295.
Burke, L., & Kamal, S. (1995). Neural networks and the part family/machine group formation problem in cellular manufacturing: a framework using fuzzy ART. *Journal of Manufacturing Systems, 14*(3), 148-159.
Castejón-Limas, M., Ordieres-Meré, J., González-Marcos, A., & González-Castro, V. (2011). Effort estimates through project complexity. *Annals of Operations Research, 186*(1), 395-406.

Cesaní, V. I., & Steudel, H. J. (2005). A study of labor assignment flexibility in cellular manufacturing systems. *Computers & industrial engineering, 48*(3), 571-591.
Chan, F. T., Lau, K. W., Chan, P. L. Y., & Choy, K. L. (2006). Two-stage approach for machine-part grouping and cell layout problems. *Robotics and Computer-Integrated Manufacturing, 22*(3), 217-238.
Chandrasekharan, M., & Rajagopalan, R. (1987). ZODIAC—an algorithm for concurrent formation of part-families and machine-cells. *International Journal of Production Research, 25*(6), 835-850.
Chattopadhyay, M., Dan, P. K., & Mazumdar, S. (2012). Application of visual clustering properties of self organizing map in machine–part cell formation. *Applied Soft Computing, 12*(2), 600-610.
Chen, J.-S., & Heragu, S. S. (1999). Stepwise decomposition approaches for large scale cell formation problems. *European Journal of Operational Research, 113*(1), 64-79.
Chen, J.-S., & Park, S. (1996). An improved ART neural net for machine cell formation. *Journal of materials processing technology, 61*(1), 1-6.
Chitta, R., & Narasimha Murty, M. (2010). Two-level< i> k</i>-means clustering algorithm for< i> k</i>–τ relationship establishment and linear-time classification. *Pattern Recognition, 43*(3), 796-804.
Chow, W. S., & Hawaleshka, O. (1992). An efficient algorithm for solving the machine chaining problem in cellular manufacturing. *Computers & industrial engineering, 22*(1), 95-100.
Chtourou, H., & Haouari, M. (2008). A two-stage-priority-rule-based algorithm for robust resource-constrained project scheduling. *Computers & industrial engineering, 55*(1), 183-194.
Damay, J., Quilliot, A., & Sanlaville, E. (2007). Linear programming based algorithms for preemptive and non-preemptive RCPSP. *European Journal of Operational Research, 182*(3), 1012-1022.
De Jong, K. A. (1975). Analysis of the behavior of a class of genetic adaptive systems.
De Reyck, B. (1998). A branch-and-bound procedure for the resource-constrained project scheduling problem with generalized precedence relations. *European Journal of Operational Research, 111*(1), 152-174.
Defersha, F. M., & Chen, M. (2006). A comprehensive mathematical model for the design of cellular manufacturing systems. *International Journal of Production Economics, 103*(2), 767-783.
Demeulemeester, E. L., & Herroelen, W. S. (1996). An efficient optimal solution procedure for the preemptive resource-constrained project scheduling problem. *European Journal of Operational Research*, *90*(2), 334-348.
Deutsch, S. J., Freeman, S. F., & Helander, M. (1998). Manufacturing cell formation using an improved< i> P</i>-median model. *Computers & industrial engineering, 34*(1), 135-146.
Dimopoulos, C., & Mort, N. (2001). A hierarchical clustering methodology based on genetic programming for the solution of simple cell-formation problems. *International Journal of Production Research, 39*(1), 1-19.
Dorigo, M. (1992). Optimization, learning and natural algorithms. *Ph. D. Thesis, Politecnico di Milano, Italy*.
Drolet, J., Abdulnour, G., & Rheault, M. (1996). The cellular manufacturing evolution. *Computers & industrial engineering, 31*(1), 139-142.
Dunn, J. (1974). Some recent investigations of a new fuzzy partitioning algorithm and its application to pattern classification problems.

Durmusoglu, M. B., & Nomak, A. (2005). GT cells design and implementation in a glass mould production system. *Computers & industrial engineering, 48*(3), 525-536.

Eberhart, R., & Kennedy, J. (1995). A new optimizer using particle swarm theory. Paper presented at the Micro Machine and Human Science, 1995. MHS'95., Proceedings of the Sixth International Symposium on.

Egilmez, G., & Süer, G. (2014). The impact of risk on the integrated cellular design and control. *International Journal of Production Research, 52*(5), 1455-1478.

Eiben, A. E., Hinterding, R., & Michalewicz, Z. (1999). Parameter control in evolutionary algorithms. *Evolutionary Computation, IEEE Transactions on, 3*(2), 124-141.

Elmaghraby, S. E., & Herroelen, W. S. (1990). The scheduling of activities to maximize the net present value of projects. *European Journal of Operational Research, 49*(1), 35-49.

Elmi, A., Solimanpur, M., Topaloglu, S., & Elmi, A. (2011). A simulated annealing algorithm for the job shop cell scheduling problem with intercellular moves and reentrant parts. *Computers & industrial engineering, 61*(1), 171-178.

Enke, D., Ratanapan, K., & Dagli, C. (1998). Machine-part family formation utilizing an ART1 neural network implemented on a parallel neuro-computer. *Computers & industrial engineering, 34*(1), 189-205.

Enke, D., Ratanapan, K., & Dagli, C. (2000). Large machine-part family formation utilizing a parallel ART1 neural network. *Journal of Intelligent Manufacturing, 11*(6), 591-604.

Ertay, T., & Ruan, D. (2005). Data envelopment analysis based decision model for optimal operator allocation in CMS. *European Journal of Operational Research, 164*(3), 800-810.

Etgar, R., Shtub, A., & LeBlanc, L. J. (1997). Scheduling projects to maximize net present value—the case of time-dependent, contingent cash flows. *European Journal of Operational Research, 96*(1), 90-96.

Fitzpatrick, E. L., & Askin, R. G. (2005). Forming effective worker teams with multi-functional skill requirements. *Computers & industrial engineering, 48*(3), 593-608.

Gel, E., Hopp, W., & Van Oyen, M. (2000). Workforce agility in systems with hierarchical cross-training: working paper, Northwestern University Evanston, IL.

Glover, F. (1986). Future paths for integer programming and links to artificial intelligence. *Computers & Operations Research, 13*(5), 533-549.

Goldengorin, B., Krushinsky, D., & Slomp, J. (2012). Flexible PMP approach for large-size cell formation. *Operations Research, 60*(5), 1157-1166.

Goncalves Filho, V., & José Tiberti, A. (2006). A group genetic algorithm for the machine cell formation problem. *International Journal of Production Economics, 102*(1), 1-21.

Gonçalves, J. F., & Resende, M. G. (2004). An evolutionary algorithm for manufacturing cell formation. *Computers & industrial engineering, 47*(2), 247-273.

Gravel, M., Luntala Nsakanda, A., & Price, W. (1998). Efficient solutions to the cell-formation problem with multiple routings via a double-loop genetic algorithm. *European Journal of Operational Research, 109*(2), 286-298.

Grinold, R. C. (1972). The payment scheduling problem. *Naval Research Logistics Quarterly, 19*(1), 123-136.

Grznar, J., Mehrez, A., & Felix Offodile, O. (1994). Formulation of the machine cell grouping problem with capacity and material movement constraints. *Journal of Manufacturing Systems, 13*(4), 241-250.

Gu, P. (1991). Process-based machine grouping for cellular manufacturing systems. *Computers in industry, 17*(1), 9-17.

Guerrero, F., Lozano, S., Smith, K. A., Canca, D., & Kwok, T. (2002). Manufacturing cell formation using a new self-organizing neural network. *Computers & industrial engineering, 42*(2), 377-382.

Gupta, T. (1991). Clustering algorithms for the design of a cellular manufacturing system—an analysis of their performance. *Computers & industrial engineering, 20*(4), 461-468.

Gupta, T., & Seifoddini, H. I. (1990). Production data based similarity coefficient for machine-component grouping decisions in the design of a cellular manufacturing system. *International Journal of Production Research, 28*(7), 1247-1269.

Haleh, H., Iranmanesh, H., & Kor, H. (2009). A new hybrid evolutionary algorithm for solving multi objective cell formation problem. Paper presented at the Computers & Industrial Engineering, 2009. CIE 2009. International Conference on.

Harhalakis, G., Nagi, R., & Proth, J. (1990). An efficient heuristic in manufacturing cell formation for group technology applications. *International Journal of Production Research, 28*(1), 185-198.

Hartmann, S. (2001). Project scheduling with multiple modes: a genetic algorithm. *Annals of Operations Research, 102*(1-4), 111-135.

Hassan, M. (1995). Layout design in group technology manufacturing. *International Journal of Production Economics, 38*(2), 173-188.

Heady, R. B. (1997). Forming minimum-cost machine cells with exceptional parts using zero-one integer programming. *Journal of Manufacturing Systems, 16*(2), 79-90.

Heragu, S. S. (1989). Knowledge based approach to machine cell layout. *Computers & industrial engineering, 17*(1), 37-42.

Heragu, S. S., & Chen, J.-S. (1998). Optimal solution of cellular manufacturing system design: Benders' decomposition approach. *European Journal of Operational Research, 107*(1), 175-192.

Heragu, S. S., & Kusiak, A. (1988). Machine layout problem in flexible manufacturing systems. *Operations Research, 36*(2), 258-268.

Heragu, S. S., & Kusiak, A. (1991). Efficient models for the facility layout problem. *European Journal of Operational Research, 53*(1), 1-13.

Holland, J. (1975). 1975, Adaptation in Natural and Artificial Systems, University of Michigan Press, Ann Arbor.

Hsu, C.-M., & Su, C.-T. (1998). Multi-objective machine-component grouping in cellular manufacturing: a genetic algorithm. *Production Planning & Control, 9*(2), 155-166.

Hyer, N., & Wemmerlov, U. (2002). *Reorganizing the factory: Competing through cellular manufacturing*: Productivity Press.

Icmeli, O., & Erenguc, S. S. (1994). A tabu search procedure for the resource constrained project scheduling problem with discounted cash flows. *Computers & operations research, 21*(8), 841-853.

Icmeli, O., Erenguc, S. S., & Zappe, C. J. (1993). Project scheduling problems: a survey. *International Journal of Operations & Production Management, 13*(11), 80-91.

Inho, J., & Rhee, J. (1997). Generalized machine cell formation considering material flow and plant layout using modified self-organizing feature maps. *Computers & industrial engineering, 33*(3), 457-460.
Irani, S. A., & Huang, H. (2000). Custom design of facility layouts for multiproduct facilities using layout modules. *Robotics and Automation, IEEE Transactions on, 16*(3), 259-267.
Izakian, H., & Abraham, A. (2011). Fuzzy C-means and fuzzy swarm for fuzzy clustering problem. *Expert Systems with Applications, 38*(3), 1835-1838.
Jensen, J. B. (2000). The impact of resource flexibility and staffing decisions on cellular and departmental shop performance. *European Journal of Operational Research, 127*(2), 279-296.
Jeon, G., & Leep, H. R. (2006). Forming part families by using genetic algorithm and designing machine cells under demand changes. *Computers & operations research, 33*(1), 263-283.
Josien, K., & Liao, T. W. (2002). Simultaneous grouping of parts and machines with an integrated fuzzy clustering method. *Fuzzy sets and systems, 126*(1), 1-21.
Kao, Y., & Li, Y. (2008). Ant colony recognition systems for part clustering problems. *International Journal of Production Research, 46*(15), 4237-4258.
Karmarkar, U. S., Kekre, S., & Kekre, S. (1987). Capacity analysis of a manufacturing cell. *Journal of Manufacturing Systems, 6*(3), 165-175.
Kaufman, L., & Rousseeuw, P. J. (2009). *Finding groups in data: an introduction to cluster analysis* (Vol. 344): Wiley. com.
Ke, H., & Liu, B. (2010). Fuzzy project scheduling problem and its hybrid intelligent algorithm. *Applied Mathematical Modelling, 34*(2), 301-308.
Kelle, P., & Milne, A. (1999). The effect of (s, S) ordering policy on the supply chain. *International Journal of Production Economics, 59*(1), 113-122.
Kelley, J. E. (1963). The critical-path method: Resources planning and scheduling. *Industrial scheduling, 13*, 347-365.
Kher, H. V. (2000). Examination of flexibility acquisition policies in dual resource constrained job shops with simultaneous worker learning and forgetting effects. *Journal of the Operational Research Society*, 592-601.
Kim, K., Yun, Y., Yoon, J., Gen, M., & Yamazaki, G. (2005). Hybrid genetic algorithm with adaptive abilities for resource-constrained multiple project scheduling. *Computers in industry, 56*(2), 143-160.
King, J. R. (1980). Machine-component grouping in production flow analysis: an approach using a rank order clustering algorithm. *International Journal of Production Research, 18*(2), 213-232.
King, J. R., & Nakornchai, V. (1982). Machine-component group formation in group technology: review and extension. *International Journal of Production Research, 20*(2), 117-133.
Kirkpatrick, S. (1984). Optimization by simulated annealing: Quantitative studies. *Journal of statistical physics, 34*(5-6), 975-986.
Kleiner, B. M., Drury, C. G., & Palepu, P. (1998). A computer-based productivity and quality management system for cellular manufacturing. *Computers & industrial engineering, 34*(1), 207-217.
Kohonen, T. (1989). Self-organizing and associative memory. *Springer, Berlin*.
Kolisch, R. (1996). Serial and parallel resource-constrained project scheduling methods revisited: Theory and computation. *European Journal of Operational Research, 90*(2), 320-333.
Kolisch, R., & Drexl, A. (1997). Local search for nonpreemptive multi-mode resource-constrained project scheduling. *IIE transactions, 29*(11), 987-999.

Krushinsky, D., & Goldengorin, B. (2012). An exact model for cell formation in group technology. *Computational Management Science, 9*(3), 323-338.
Kulak, O., Durmusoglu, M., & Tufekci, S. (2005). A complete cellular manufacturing system design methodology based on axiomatic design principles. *Computers & industrial engineering, 48*(4), 765-787.
Kulkarni, U. R., & Kiang, M. Y. (1995). Dynamic grouping of parts in flexible manufacturing systems—a self-organizing neural networks approach. *European Journal of Operational Research, 84*(1), 192-212.
Kuo, R., Su, Y., Chiu, C., Chen, K.-Y., & Tien, F.-C. (2006). Part family formation through fuzzy ART2 neural network. *Decision Support Systems, 42*(1), 89-103.
Kusiak, A. (1987). The generalized group technology concept. *International Journal of Production Research, 25*(4), 561-569.
Kusiak, A. (1991). Branching algorithms for solving the group technology problem. *Journal of Manufacturing Systems, 10*(4), 332-343.
Land, A. H., & Doig, A. G. (1960). An automatic method of solving discrete programming problems. *Econometrica: Journal of the Econometric Society*, 497-520.
Laslo, Z. (2010). Project portfolio management: An integrated method for resource planning and scheduling to minimize planning/scheduling-dependent expenses. *International Journal of Project Management, 28*(6), 609-618.
Lee-Post, A. (2000). Part family identification using a simple genetic algorithm. *International Journal of Production Research, 38*(4), 793-810.
Lee, & Lei, L. (2001). Multiple-project scheduling with controllable project duration and hard resource constraint: some solvable cases. *Annals of Operations Research, 102*(1-4), 287-307.
Lee, Malavé, C. O., & Ramachandran, S. (1992). A self-organizing neural network approach for the design of cellular manufacturing systems. *Journal of Intelligent Manufacturing, 3*(5), 325-332.
Li, Q., Gong, J., Fung, R. Y., & Tang, J. (2012). Multi-objective optimal cross-training configuration models for an assembly cell using non-dominated sorting genetic algorithm-II. *International Journal of Computer Integrated Manufacturing, 25*(11), 981-995.
Logendran, R., & Talkington, D. (1997). Analysis of cellular and functional manufacturing systems in the presence of machine breakdown. *International Journal of Production Economics, 53*(3), 239-256.
Lova, A., & Tormos, P. (2001). Analysis of scheduling schemes and heuristic rules performance in resource-constrained multiproject scheduling. *Annals of Operations Research, 102*(1-4), 263-286.
Lozano, S., Dobado, D., Larrañeta, J., & Onieva, L. (2002). Modified fuzzy C-means algorithm for cellular manufacturing. *Fuzzy sets and systems, 126*(1), 23-32.
Luxhøj, J. T., Riis, J. O., & Thorsteinsson, U. (1997). Trends and perspectives in industrial maintenance management. *Journal of manufacturing systems, 16*(6), 437-453.
Mahdavi, I., Aalaei, A., Paydar, M. M., & Solimanpur, M. (2010). Designing a mathematical model for dynamic cellular manufacturing systems considering production planning and worker assignment. *Computers & Mathematics with Applications, 60*(4), 1014-1025.
Mahdavi, I., Aalaei, A., Paydar, M. M., & Solimanpur, M. (2011). Multi-objective cell formation and production planning in dynamic virtual cellular manufacturing systems. *International Journal of Production Research, 49*(21), 6517-6537.

Mahdavi, I., Aalaei, A., Paydar, M. M., & Solimanpur, M. (2012). A new mathematical model for integrating all incidence matrices in multi-dimensional cellular manufacturing system. *Journal of Manufacturing Systems, 31*(2), 214-223.

Mahdavi, I., Javadi, B., Fallah-Alipour, K., & Slomp, J. (2007). Designing a new mathematical model for cellular manufacturing system based on cell utilization. *Applied Mathematics and Computation, 190*(1), 662-670.

Mahdavi, I., Kaushal, O., & Chandra, M. (2001). Graph-neural network approach in cellular manufacturing on the basis of a binary system. *International Journal of Production Research, 39*(13), 2913-2922.

Mahdavi, I., Paydar, M. M., Solimanpur, M., & Heidarzade, A. (2009). Genetic algorithm approach for solving a cell formation problem in cellular manufacturing. *Expert Systems with Applications, 36*(3), 6598-6604.

Malavé, C. O., & Ramachandran, S. (1991). Neural network-based design of cellular manufacturing systems. *Journal of Intelligent Manufacturing, 2*(5), 305-314.

McAuley, J. (1972). Machine grouping for efficient production. *Production Engineer, 51*(2), 53-57.

Mika, M., Waligóra, G., & Węglarz, J. (2005). Simulated annealing and tabu search for multi-mode resource-constrained project scheduling with positive discounted cash flows and different payment models. *European Journal of Operational Research, 164*(3), 639-668.

Molleman, E., & Slomp, J. (1999). Functional flexibility and team performance. *International Journal of Production Research, 37*(8), 1837-1858.

Moon, Y., & Chi, S. (1992). Generalized part family formation using neural network techniques. *Journal of Manufacturing Systems, 11*(3), 149-159.

Moussa, S. E., & Kamel, M. (1998). A part-machine assignment algorithm for cellular manufacturing with machine capacity constraints. *Computers & industrial engineering, 35*(3), 483-486.

Mukhopadhyay, S., Gopalakrishnan, A., & Kripalani, M. (1995). Moments-based clustering techniques for manufacturing cell formation. *The international journal of production research 33*(4), 1091-1115.

Muruganandam, A., Prabhaharan, G., Asokan, P., & Baskaran, V. (2005). A memetic algorithm approach to the cell formation problem. *The International Journal of Advanced Manufacturing Technology, 25*(9-10), 988-997.

Narayanaswamy, P., Bector, C., & Rajamani, D. (1996). Fuzzy logic concepts applied to machine—component matrix formation in cellular manufacturing. *European Journal of Operational Research, 93*(1), 88-97.

Norman, B. A., Tharmmaphornphilas, W., Needy, K. L., Bidanda, B., & Warner, R. C. (2002). Worker assignment in cellular manufacturing considering technical and human skills. *International Journal of Production Research, 40*(6), 1479-1492.

Nouri, H., Tang, S., Hang Tuah, B., & Anuar, M. (2010). BASE: A bacteria foraging algorithm for cell formation with sequence data. *Journal of Manufacturing Systems, 29*(2), 102-110.

Nsakanda, A. L., Diaby, M., & Price, W. L. (2006). Hybrid genetic approach for solving large-scale capacitated cell formation problems with multiple routings. *European Journal of Operational Research, 171*(3), 1051-1070. doi: 10.1016/j.ejor.2005.01.017

Oliveira, S., Ribeiro, J., & Seok, S. (2009). A spectral clustering algorithm for manufacturing cell formation. *Computers & industrial engineering, 57*(3), 1008-1014.

Olorunniwo, F., & Udo, G. (2002). The impact of management and employees on cellular manufacturing implementation. *International Journal of Production Economics, 76*(1), 27-38.

Onwubolu, G., & Mutingi, M. (2001). A genetic algorithm approach to cellular manufacturing systems. *Computers & industrial engineering, 39*(1), 125-144.

Özdemir, R. G., Gençyılmaz, G., & Aktin, T. (2007). The modified fuzzy art and a two-stage clustering approach to cell design. *Information Sciences, 177*(23), 5219-5236.

Pandian, R. S., & Mahapatra, S. S. (2009). Manufacturing cell formation with production data using neural networks. *Computers & industrial engineering, 56*(4), 1340-1347.

Papaioannou, G., & Wilson, J. M. (2010). The evolution of cell formation problem methodologies based on recent studies (1997–2008): Review and directions for future research. *European Journal of Operational Research, 206*(3), 509-521.

Park, & Lee, H. (1995). Design of a manufacturing cell in consideration of multiple objective performance measures. *Manufacturing research and technology, 24*, 181-202.

Park, & Suresh, N. (2003). Performance of Fuzzy ART neural network and hierarchical clustering for part-machine grouping based on operation sequences. *International Journal of Production Research, 41*(14), 3185-3216.

Passino, K. M. (2002). Biomimicry of bacterial foraging for distributed optimization and control. *Control Systems, IEEE, 22*(3), 52-67.

Paydar, M. M., Mahdavi, I., Sharafuddin, I., & Solimanpur, M. (2010). Applying simulated annealing for designing cellular manufacturing systems using MDmTSP. *Computers & industrial engineering, 59*(4), 929-936.

Paydar, M. M., & Saidi-Mehrabad, M. (2013). A hybrid genetic-variable neighborhood search algorithm for the cell formation problem based on grouping efficacy. *Computers & operations research, 40*(4), 980-990.

Peteghem, V. V., & Vanhoucke, M. (2010). A genetic algorithm for the preemptive and non-preemptive multi-mode resource-constrained project scheduling problem. *European Journal of Operational Research, 201*(2), 409-418.

Rafiee, K., Rabbani, M., Rafiei, H., & Rahimi-Vahed, A. (2011). A new approach towards integrated cell formation and inventory lot sizing in an unreliable cellular manufacturing system. *Applied Mathematical Modelling, 35*(4), 1810-1819.

Renna, P., & Ambrico, M. (2015). Design and reconfiguration models for dynamic cellular manufacturing to handle market changes. *International Journal of Computer Integrated Manufacturing, 28*(2), 170-186.

Roeva, O., Fidanova, S., & Paprzycki, M. (2013). Influence of the population size on the genetic algorithm performance in case of cultivation process modelling. Paper presented at the Computer Science and Information Systems (FedCSIS), 2013 Federated Conference on.

Rogers, D. F., & Kulkarni, S. S. (2005). Optimal bivariate clustering and a genetic algorithm with an application in cellular manufacturing. *European Journal of Operational Research, 160*(2), 423-444.

Rooij, A. v., Johnson, R. P., & Jain, L. C. (1996). *Neural network training using genetic algorithms*: World Scientific Publishing Co., Inc.

Russell, A. (1970). Cash flows in networks. *Management Science, 16*(5), 357-373.

Safaei, N., Saidi-Mehrabad, M., & Jabal-Ameli, M. (2008). A hybrid simulated annealing for solving an extended model of dynamic cellular manufacturing system. *European Journal of Operational Research, 185*(2), 563-592. doi: 10.1016/j.ejor.2006.12.058

Safaei, N., & Tavakkoli-Moghaddam, R. (2009a). An extended fuzzy parametric programming-based approach for designing cellular manufacturing systems under uncertainty and dynamic conditions. *International Journal of Computer Integrated Manufacturing, 22*(6), 538-548.

Safaei, N., & Tavakkoli-Moghaddam, R. (2009b). Integrated multi-period cell formation and subcontracting production planning in dynamic cellular manufacturing systems. *International Journal of Production Economics, 120*(2), 301-314.

Sarker, & Yu, J. (1994). A two-phase procedure for duplicating bottleneck machines in a linear layout, cellular manufacturing system. *The international journal of production research 32*(9), 2049-2066.

Sarker, & Yu, J. (2007). A quadra-directional decomposition heuristic for a two-dimensional, non-equidistant machine-cell location problem. *Computers & operations research, 34*(1), 107-151.

Satoglu, S. I., & Suresh, N. C. (2009). A goal-programming approach for design of hybrid cellular manufacturing systems in dual resource constrained environments. *Computers & industrial engineering, 56*(2), 560-575.

Schaffer, J. D., Caruana, R. A., Eshelman, L. J., & Das, R. (1989). A study of control parameters affecting online performance of genetic algorithms for function optimization. Paper presented at the Proceedings of the third international conference on Genetic algorithms.

Seifi, M., & Tavakkoli-Moghaddam, R. (2008). A new bi-objective model for a multi-mode resource-constrained project scheduling problem with discounted cash flows and four payment models. *Int. J. of Engineering, Transaction A: Basic, 21*(4), 347-360.

Seifoddini, H. (1988). Machine grouping—expert systems: Comparison between single linkage and average linkage clustering techniques in forming machine cells. *Computers & industrial engineering, 15*(1), 210-216.

Seifoddini, H. (1989). Single linkage versus average linkage clustering in machine cells formation applications. *Computers & industrial engineering, 16*(3), 419-426.

Seifoddini, H., & Djassemi, M. (1993). A dynamic part assignment procedure in machine cell formation. *Computers & industrial engineering, 25*(1), 473-476.

Seifoddini, H., & Djassemi, M. (1996). Improving the performance of cellular manufacturing by a dynamic part assignment approach. *Computers & industrial engineering, 30*(4), 719-726.

Shanker, R., & Vrat, P. (1998). Post design modeling for cellular manufacturing system with cost uncertainty. *International Journal of Production Economics, 55*(1), 97-109.

Slomp, J., & Molleman, E. (2000). Cross-training policies and performance of teams. Paper presented at the Group technology/cellular manufacturing world symposium.

Slomp, J., & Suresh, N. C. (2005). The shift team formation problem in multi-shift manufacturing operations. *European Journal of Operational Research, 165*(3), 708-728.

Sofianopoulou, S. (1999). Manufacturing cells design with alternative process plans and/or replicate machines. *International Journal of Production Research, 37*(3), 707-720.

Soleymanpour, M., Vrat, P., & Shankar, R. (2002). A transiently chaotic neural network approach to the design of cellular manufacturing. *International Journal of Production Research, 40*(10), 2225-2244.
Solimanpur, M., Vrat, P., & Shankar, R. (2004). Ant colony optimization algorithm to the inter-cell layout problem in cellular manufacturing. *European Journal of Operational Research, 157*(3), 592-606.
Song, S.-J., & Hitomi, K. (1996). Integrating the production planning and cellular layout for flexible cellular manufacturing. *Production Planning & Control, 7*(6), 585-593.
Spiliopoulos, K., & Sofianopoulou, S. (1998). An optimal tree search method for the manufacturing systems cell formation problem. *European Journal of Operational Research, 105*(3), 537-551.
Sprecher, A. (2000). Scheduling resource-constrained projects competitively at modest memory requirements. *Management Science, 46*(5), 710-723.
Srinivasan, G. (1994). A clustering algorithm for machine cell formation in group technology using minimum spanning trees. *International Journal of Production Research, 32*(9), 2149-2158.
Srinivasan, G., & Narendran, T. (1991). GRAFICS—a nonhierarchical clustering algorithm for group technology. *International Journal of Production Research, 29*(3), 463-478.
Suer, G. A., & Cedeño, A. A. (1996). A configuration-based clustering algorithm for family formation. *Computers & industrial engineering, 31*(1), 147-150.
Süer, G. A., & Ortega, M. (1994). A machine level based-similarity coefficient for forming manufacturing cells. *Computers & industrial engineering, 27*(1), 67-70.
Sung, C., & Lim, S. (1994). A project activity scheduling problem with net present value measure. *International Journal of Production Economics, 37*(2), 177-187.
Suresh, N., Slomp, J., & Kaparthi, S. (1999). Sequence-dependent clustering of parts and machines: a Fuzzy ART neural network approach. *International Journal of Production Research, 37*(12), 2793-2816.
Taj, S., Cochran, D. S., Duda, J. W., & Linck, J. (1998). Simulation and production planning for manufacturing cells. Paper presented at the Proceedings of the 30th conference on Winter simulation.
Talbi, E.-G. (2009). *Metaheuristics: from design to implementation* (Vol. 74): John Wiley & Sons.
Talbot, F. B. (1982). Resource-constrained project scheduling with time-resource tradeoffs: The nonpreemptive case. *Management Science, 28*(10), 1197-1210.
Tarsuslugil, M., & Bloor, J. (1979). The use of similarity coefficients and cluster analysis in production flow analysis. Paper presented at the Proceedings of 20th International Machine Tool Design and Research Conference.
Tavakkoli-Moghaddam, R., Aryanezhad, M.-B., Safaei, N., & Azaron, A. (2005). Solving a dynamic cell formation problem using metaheuristics. *Applied Mathematics and Computation, 170*(2), 761-780. doi: 10.1016/j.amc.2004.12.021
Tavakkoli-Moghaddam, R., Aryanezhad, M.-B., Safaei, N., Vasei, M., & Azaron, A. (2007). A new approach for the cellular manufacturing problem in fuzzy dynamic conditions by a genetic algorithm. *Journal of Intelligent and Fuzzy Systems, 18*(4), 363-376.
Tavakkoli-Moghaddam, R., Javadian, N., Javadi, B., & Safaei, N. (2007). Design of a facility layout problem in cellular manufacturing systems with stochastic

demands. *Applied Mathematics and Computation, 184*(2), 721-728. doi: 10.1016/j.amc.2006.05.172
Tavakkoli-Moghaddam, R., Safaei, N., & Babakhani, M. (2005). Solving a dynamic cell formation problem with machine cost and alternative process plan by memetic algorithms *Stochastic Algorithms: Foundations and Applications* (pp. 213-227): Springer.
Theodoridis, S., Pikrakis, A., Koutroumbas, K., & Cavouras, D. (2010). *Introduction to Pattern Recognition: A Matlab Approach: A Matlab Approach*: Access Online via Elsevier.
Tompkins, J., White, J., Bozer, Y., & Tanchoco, J. (2003). Facilities planning. 2003: Wiley, New York.
Ünler, A., & Güngör, Z. (2009). Applying K-harmonic means clustering to the part-machine classification problem. *Expert Systems with Applications, 36*(2), 1179-1194.
Van de Vonder, S., Demeulemeester, E., Herroelen, W., & Leus, R. (2005). The use of buffers in project management: The trade-off between stability and makespan. *International Journal of Production Economics, 97*(2), 227-240.
Van de Vonder, S., Demeulemeester, E., Herroelen, W., & Leus, R. (2006). The trade-off between stability and makespan in resource-constrained project scheduling. *International Journal of Production Research, 44*(2), 215-236.
Venkumar, P., & Haq, A. N. (2006a). Complete and fractional cell formation using Kohonen self-organizing map networks in a cellular manufacturing system. *International Journal of Production Research, 44*(20), 4257-4271.
Venkumar, P., & Haq, A. N. (2006b). Fractional cell formation in group technology using modified ART1 neural networks. *The International Journal of Advanced Manufacturing Technology, 28*(7-8), 761-765.
Venugopal, V., & Narendran, T. (1993). Design of cellular manufacturing systems based on asymptotic forms of a boolean matrix. *European Journal of Operational Research, 67*(3), 405-417.
Wang, & Roze, C. (1997). Formation of machine cells and part families: a modified p-median model and a comparative study. *International Journal of Production Research, 35*(5), 1259-1286.
Wang, & Sarker, B. R. (2002). Locating cells with bottleneck machines in cellular manufacturing systems. *International Journal of Production Research, 40*(2), 403-424.
Wang, Wu, K.-B., & Liu, Y. (2001). A simulated annealing algorithm for facility layout problems under variable demand in cellular manufacturing systems. *Computers in industry, 46*(2), 181-188.
Wei, J. C., & Kern, G. M. (1989). Commonality analysis: a linear cell clustering algorithm for group technology. *International Journal of Production Research, 27*(12), 2053-2062.
Wemmerlöv, U., & Hyer, N. L. (1986). Procedures for the part family/machine group identification problem in cellular manufacturing. *Journal of Operations Management, 6*(2), 125-147.
Wilhelm, W., Chiou, C., & Chang, D. (1998). Integrating design and planning considerations in cellular manufacturing. *Annals of Operations Research, 77*, 97-107.
Won. (2000). Two-phase approach to GT cell formation using efficient p-median formulations. *International Journal of Production Research, 38*(7), 1601-1613.

Won, & Chang Lee, K. (2004). Modified< i> p</i>-median approach for efficient GT cell formation. *Computers & industrial engineering, 46*(3), 495-510.

Won, & Currie, K. (2007). Fuzzy ART/RRR-RSS: a two-phase neural network algorithm for part-machine grouping in cellular manufacturing. *International Journal of Production Research, 45*(9), 2073-2104.

Won, & Currie, K. R. (2006). An effective< i> p</i>-median model considering production factors in machine cell/part family formation. *Journal of Manufacturing Systems, 25*(1), 58-64.

Won, & Kim, S. (1997). Multiple criteria clustering algorithm for solving the group technology problem with multiple process routings. *Computers & industrial engineering, 32*(1), 207-220. doi: 10.1016/S0360-8352(96)00209-4

Xambre, A. R., & Vilarinho, P. M. (2003). A simulated annealing approach for manufacturing cell formation with multiple identical machines. *European Journal of Operational Research, 151*(2), 434-446.

Yang, Hung, W.-L., & Cheng, F.-C. (2006). Mixed-variable fuzzy clustering approach to part family and machine cell formation for GT applications. *International Journal of Production Economics, 103*(1), 185-198.

Yang, Hwang, P.-Y., & Chen, D.-H. (2004). Fuzzy clustering algorithms for mixed feature variables. *Fuzzy sets and systems, 141*(2), 301-317.

Yang, Sun, T., & Zhang, C. (2009). An efficient hybrid data clustering method based on K-harmonic means and Particle Swarm Optimization. *Expert Systems with Applications, 36*(6), 9847-9852.

Yang, Talbot, F. B., & Patterson, J. H. (1993). Scheduling a project to maximize its net present value: an integer programming approach. *European Journal of Operational Research, 64*(2), 188-198.

Yang, & Yang, J.-H. (2008). Machine-part cell formation in group technology using a modified ART1 method. *European Journal of Operational Research, 188*(1), 140-152.

Yu, & Sarker, B. R. (2003). Directional decomposition heuristic for a linear machine-cell location problem. *European Journal of Operational Research, 149*(1), 142-184.

Yu, & Sarker, B. R. (2006). A directional decomposition heuristic for one-dimensional, non-equidistant machine-cell location problems. *Computers & operations research, 33*(1), 64-92.

Yu, Wang, S., Wen, F., & Lai, K. K. (2012). Genetic algorithm-based multi-criteria project portfolio selection. *Annals of Operations Research, 197*(1), 71-86.

Zhang. (2011). Modeling complexity of cellular manufacturing systems. *Applied Mathematical Modelling, 35*(9), 4189-4195.

Zhang, Hsu, M., & Dayal, U. (1999). K-harmonic means-a data clustering algorithm. *Hewlett-Packard Labs Technical Report HPL-1999-124*.

Zhao, L., Tsujimura, Y., & Gen, M. (1996). Genetic algorithm for fuzzy clustering. Paper presented at the Evolutionary Computation, 1996., Proceedings of IEEE International Conference on.

Zhou, M., & Askin, R. G. (1998). Formation of general GT cells: an operation-based approach. *Computers & industrial engineering, 34*(1), 147-157.

Zhu, D., & Padman, R. (1999). A metaheuristic scheduling procedure for resource-constrained projects with cash flows. *Naval Research Logistics (NRL), 46*(8), 912-927.

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[1] Icecream Production Line. Retrieved at 21/1/2016 from http://www.allposters.com/-sp/Ice-Cream-Production-Line-Posters_i10042383_.htm

[2] Images of a glass cutting and forming company. Retrived at 25.05.2013 from http:/www.arianshisheh.com/.

[3] Images of a cellular manufacturing systems. Retrived at 25.05.2013 from http:/www.amirnia.com.

[4] Definition of the term"inflation". Retrieved at 25/4/2013 from http://www.investopedia.com/university/inflation/inflation1.asp.

[5] Monthly inflation rate of some countries. Retrieved at 25/8/2015 from http://www.tradingeconomics.com

[6] Increasing in material and energy prics. Retrieved at 26.01.2016 from http://www.wikinvest.com/stock/E.I._du_Pont_de_Nemours_&_Company_(DD)/Price_Increases_Energy_Costs_Raw_Materials_Significant_Impact

[7] Currecny drop. Retrieved at 21/8/2015 from http://www.investopedia.com/articles/economics/08/currency-crises.asp

[8] Global Financial Crisis. Retrieved at 14.04.2013 from http://www.globalissues.org/article/768/global-financial-crisis

[9] Report of GDP of USA in 2013. Retrieved at 21/8/2015 from http://www.tradingeconomics.com/.

[10] Job-less rate of the USA in 2013. Retrieved at 05/04/2014 from http://www.usgovernmentspending.com/year_spending_2013USbn_15bs2n_2025#usgs302.

[11] Formula of Central Limit Theorm. Retrieved at 25/8/2015 from http://www.math.csusb.edu/faculty/stanton/probstat/clt.html.

[12] Sample size in Central Limit Theorm. Retrieved at 11/3/2013 from http://www.math.uah.edu/stat/sample/CLT.html.

[13] GDP deflator rates from 2010 to 2013. Retrieved at 25/8/2015 from http://data.worldbank.org/indicator/NY.GDP.DEFL.KD.ZG.

[14] Intorduction of Heuristic Algorithms. Retrieved at 25/02/2015 from http://students.ceid.upatras.gr/~papagel/project/kef5_5.htm

[15] Reasons for choosing Metaheuristics. Retrieved at 25/02/2015 from http://scholarpedia.org/article/Metaheuristics.

[16] Monthly inflation rate of Malaysia. Retrieved at 25/8/2015 from http://www.tradingeconomics.com