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# **Construction Research Congress 2009: Building a Sustainable Future**

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Building a Sustainable

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Proceedings of Construction Research Congress 2009, held in Seattle, Washington, April 5-7, 2009. Sponsored by Construction Institute of ASCE; University of Washington. This collection contains 152 peerreviewed papers organized into general state-of-knowledge research areas in construction engineering and management. Topics include: project control; general operations issues; procurement and contracting; organizational leadership and management; advances in project planning, design, and construction; sustainable construction and facilities; project risks and safety; project planning and control; project and process integration and improvement; lean construction.

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 Querying IFC-Based Building Information Models to Support Construction Management Functions



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- An Automated Tool for Identifying the Implications of Changes in
- Construction Projects
  Ronie Navon and Shabtai Isaac
  pp. 1-10 (10 pages)
  http://dx.doi.org/10.1061/41020(339)1
  Abstract | PDF (480 KB) | Permissions
  - <u>-</u> The impact of changes in construction projects often becomes clear only after their implementation, when it is difficult to make

adjustments or consider alternatives. A model which identifies the impact of proposed changes on the primary client objectives of cost, schedule and performance is currently under development. The model utilizes available sources of project information in order to identify the impact of changes prior to their implementation in the project. The model should be integrative, adaptive and stochastic. The basic aspects of the model are, accordingly, that it links the primary client objectives; that it is defined using a graph-based approach; and, that it represents project information as a stochastic network. Different change scenarios can be investigated using the model, and their consequences are quickly identified by tracing the relationships between the elements of the project.

Development of Human Pose Analyzing Algorithms for the Determination of Construction Productivity in Real-Time Abhinav Peddi, Luke Huan, Yong Bai, and Seonghoon Kim pp. 11-20 (10 pages) | Cited 2 times http://dx.doi.org/10.1061/41020(339)2
Abstract | PDF (1166 KB) | Permissions

To enhance the capability of rapid construction, an automated onsite productivity measurement system is developed. Employing the concepts of Computer Vision and Artificial Intelligence, the developed system wirelessly acquires a sequence of images of construction activities. The system first processes these images in real-time to generate human poses associated with the construction workers at a project site. The poses are first manually classified into three categories as effective work, ineffective work, and contributory work. Then, a built-in neural network trained on these classifications, determines the worker's status by comparing the incoming images to the developed human poses. The labor productivity is determined from these comparison statistics. This

productivity is determined from these comparison statistics. This system has been tested for accuracy on a bridge construction project. The analysis results were accurate as compared to the results of the manual method. This research project made several major contributions to the advancement in construction industry. First, it applied advanced image processing techniques for analyzing construction operations. Second, the results of this research project made possible the automatic determination of construction productivity in real-time. Thus, an instant feedback to the construction crew was possible. As a result, the capability of rapid construction was improved using the developed technology.

Benefits and Barriers of Monitoring Construction Activities Using

Hi-Resolution Automated Cameras
Jeffrey S. Bohn and Jochen Teizer
pp. 21-30 (10 pages)
http://dx.doi.org/10.1061/41020(339)3
Abstract | PDF (676 KB) | Permissions

Monitoring construction projects is a constant task for project managers and executives. The shear size of many projects makes complete coverage difficult and time consuming. Emerging technologies are entering the industry to aid workers in maintaining

project controls, but additional research is needed to clearly identify benefits and barriers associated with their use, as historically, data has not been collected in this area. Hi-Resolution construction cameras can allow project managers to see a broader perspective of construction activities and operations and allow these people to do so anywhere internet connectivity is available. This paper focuses on creating a standard approach to quantify cost-benefits of new technologies, specifically construction cameras. Results of a multiphased survey to industry professionals were collected in order to identify benefits and barriers and develop a cost-benefit model for implementation of new technology in construction.

- Pro-Active-Real-Time Personnel Warning System
- Clare E. Fullerton, Ben S. Allread, and Jochen Teizer pp. 31-40 (10 pages)
  <a href="http://dx.doi.org/10.1061/41020(339)4">http://dx.doi.org/10.1061/41020(339)4</a>
  <a href="https://dx.doi.org/10.1061/41020(339)4">Abstract | PDF (755 KB) | Permissions</a>

Collisions between personnel on foot and heavy equipment or materials on a construction site can be characterized as a contact collision. These types of incidents are a common occurrence on a work site. Pro-active-real-time safety technology is needed to improve the safety of a work zone by alerting workers that they are in danger of collisions. Furthermore technology may assist to collect (previously unrecorded) data on "near-misses". This new approach can then lead to improve the overall safety performance in construction and elsewhere through improved learning and education by providing relevant information to decision makers at all levels. The technology that was developed and is presented in this paper uses the radio frequency wave spectrum to alert workers in real-time when they are in danger. Various experiments are described that have been conducted in order to gain better understanding of the technology's potential, including machine blind spots. Preliminary results are demonstrated and will conclude that this technology also has the capability of collecting important safety data while pro-actively detecting hazardous situations and warning workers and equipment operators of an imminent predicament.

Interactive Visual Construction Progress Monitoring with D<sup>4</sup> AR

— 4D Augmented Reality — Models

Mani Golparvar-Fard, Silvio Savarese, and Feniosky Peña-Mora

pp. 41-50 (10 pages) | Cited 2 times

http://dx.doi.org/10.1061/41020(339)5

Abstract | PDF (4598 KB) | Permissions

Visualization of construction progress helps construction project managers to study spatial aspects of as-built and as-planned performances, identify progress discrepancies, better utilize resources and equipments in different locations and make timely corrective decisions. This needs as-built performance model to be generated and superimposed over as-planned allowing progress discrepancies to be visualized. In this paper we discuss methodology of generating, analyzing and visualizing progress with

D<sup>4</sup>AR (4 Dimensional Augmented Reality) models using daily construction photographs and 4D as-planned model. We use three construction cases to illustrate how the as-built progress models could be sparsely reconstructed using daily site photographs and how the reconstructed model is superimposed over the as-planned model. We also demonstrate how the D<sup>4</sup>AR model is applied in these ongoing construction projects. As a result of this research, automatic and more frequent visual progress data collection, analysis and reporting will become possible.

Visualization Application for Interior Progress Monitoring in 3D

Environment

<u>Seungjun Roh, Feniosky Peña-Mora, Mani Golparvar Fard,</u> and <u>SangUk Han</u>

pp. 51-60 (10 pages)

http://dx.doi.org/10.1061/41020(339)6

Abstract | PDF (1313 KB) | Permissions

In the interior construction of building projects, a significant amount of schedule delay is caused by an inability of realistic appreciation the complicated interior work. Using computer visualization techniques, such as 4D or Augmented Reality (AR) model and color and pattern coding, users may compare the asplanned with the as-built interior construction progress. These technologies therefore play an increasing role in automatically analyzing the progress of complicated interior construction works, visualizing its progress condition, and making appropriate and quick corrective decisions. This paper introduces a visualization application that enables the user to monitor interior construction progress efficiently using construction photographs superimposed over a 3D model. This prototype of application represents as-built interior construction photographs, user's viewing point information, and the status of construction progress. This application allows the user to walk-through the 3D environment so that the user has an intuitive understand of the interior construction progress represented with colors and patterns.

Automated Data Acquisition System to Assess Construction

Worker Performance

I. P. Tharindu Weerasinghe and Janaka Y. Ruwanpura

pp. 61-70 (10 pages)

http://dx.doi.org/10.1061/41020(339)7

Abstract | PDF (1056 KB) | Permissions

This paper presents a real time and fully automated system using signal processing techniques for data extraction from digital video images, audio files and thermal images of construction work activities. This data extraction system is developed to detect the construction workers and their movements within a given work area to measure tool time and to assess worker productivity. The worker tracking system is based on the characteristics of the hardhat extracted from digital videos to differentiate worker from others such as supervisors and engineers. Furthermore, the work status of the worker is tracked using Infrared cameras and unidirectional

microphones. Thermal images extracted from infrared cameras recognize whether the worker is working or idle. The audio files from the microphones identify the sound wave patterns of the worker tools. This real time and automated information is expected to measure the tool time and productivity of a given work within a specific time period. The information extracted and analysed from the system will certainly aid the project managers to better plan to optimize labor and crews to achieve the expected productivity.

- Project Information Management in Mega Oil Sands Projects
- Zonghai Han and Thomas Froese
  pp. 71-80 (10 pages)
  http://dx.doi.org/10.1061/41020(339)8
  Abstract | PDF (435 KB) | Permissions

Emerging Information and Communication Technologies offer major improvements to the practice of project management in the construction industry, yet these systems are complex and are not easily adopted into current practice. Furthermore, experiences with transformative information and communications technologies in other industries suggest that these benefits cannot be fully realized unless the overall work processes and management practices also evolve. This suggests that current work in construction project information and communications technologies cannot achieve its full potential unless we also develop our practices for managing information on projects. Project Information Management (PIM)—the practice of managing a construction project's information systems—should be developed into a more formal and explicit subdiscipline of project management. We propose an overall framework for Project Information Management, structured around

four dimensions of goals and objectives, the project elements, the information system elements, and the management practices. Case

Validation of Vision Tracking at Egnatia Odos Motorway

studies are conducted to support our proposal.

Francisco Cordova, Dimitris Sideris, Ioannis Brilakis, and Demos C. Angelides
pp. 81-90 (10 pages)

http://dx.doi.org/10.1061/41020(339)9
Abstract | PDF (2293 KB) | Permissions

Tracking applications provide real time on-site information that can be used to detect travel path conflicts, calculate crew productivity and eliminate unnecessary processes at the site. This paper presents the validation of a novel vision based tracking methodology at the Egnatia Odos Motorway in Thessaloniki, Greece. Egnatia Odos is a motorway that connects Turkey with Italy through Greece. Its

multiple open construction sites serves as an ideal multi-site test bed for validating construction site tracking methods. The vision based tracking methodology uses video cameras and computer algorithms to calculate the 3D position of project related entities (e.g. personnel, materials and equipment) in construction sites. The approach provides an unobtrusive, inexpensive way of effectively identifying and tracking the 3D location of entities. The process

followed in this study starts by acquiring video data from multiple synchronous cameras at several large scale project sites of Egnatia Odos, such as tunnels, interchanges and bridges under construction. Subsequent steps include the evaluation of the collected data and finally, performing the 3D tracking operations on selected entities (heavy equipment and personnel). The accuracy and precision of the method's results is evaluated by comparing it with the actual 3D position of the object, thus assessing the 3D tracking method's effectiveness.

Towards Establishing an Innovativeness Index for Construction

© Sites

Andrew P. McCoy pp. 91-100 (10 pages) http://dx.doi.org/10.1061/41020(339)10 Abstract | PDF (996 KB) | Permissions

The US construction industry is often characterized as laggard in its rate of adoption (innovativeness) for innovative construction products and techniques. In contrast, European construction is often considered advanced. A trip to Spain and Portugal provides a personal lens through which to view European adoption of innovation, albeit a limited view. No current index exists to compare innovation adoption across the construction setting, though. Development of this tool would therefore benefit our understanding of adoption progress in the construction industry. This work establishes such an index and uses a student-based travel abroad program to European construction sites as the setting for better understanding its design. This work therefore acts as a development step, establishing the basis for future work.

Evaluation of Work Zone Capacity Models

Carolyn Hicks, Brenda McCabe, and Susan Tighe pp. 101-110 (10 pages)
<a href="http://dx.doi.org/10.1061/41020(339)11">http://dx.doi.org/10.1061/41020(339)11</a>
<a href="https://dx.doi.org/10.1061/41020(339)11">Abstract | PDF (423 KB) | Permissions</a>

Due to aging highways, roadwork on Southern Ontario is becoming increasingly important and increasingly frequent. Lane closures that ensue from this work must be managed appropriately in order to diminish user delay costs and maintain the quality and productivity of work. The ability to predict the capacity of freeway work zones is important in this analysis. Using multiple work zones in the

- region, this study evaluated six models that were used to estimate capacity. The models were based on data from Texas, Maryland, South Carolina and Ontario. After comparing each model to the observed capacities on five sites across South Western Ontario, the resulting conclusion was that region specific models are required in order to account for local driving practices.
- The Relationship between Information Technology and
- Construction Productivity: A View from Country-Level Data
  Dong Zhai and Paul M. Goodrum
  pp. 111-120 (10 pages)

### http://dx.doi.org/10.1061/41020(339)12 Abstract | PDF (818 KB) | Permissions

With the increasing application of information technology (IT) in almost all industries, understanding the relationship between IT and productivity is useful in order to help improve the effectiveness of IT in improving productivity. Although previous research has identified the effects of IT on productivity in other industries, the general relationship between IT application and construction productivity is less clear. The evidence that overall costs have been reduced or project performance has been improved with IT in construction is limited and mostly focused on specific IT applications. This article investigates the general relationship of national IT investment level to construction productivity in various countries. The data is from Organisation for Economic Co-

- applications. This article investigates the general relationship of national IT investment level to construction productivity in various countries. The data is from Organisation for Economic Cooperation and Development (OECD) and Eurostat. By examining the trends of construction productivity and information and communication technology investment, the authors found positive relationship between these two trends among the 13 sampled European countries.
- Construction Industry Productivity: Omitted Quality Characteristics in Construction Price Indices
  Bryan D. Dyer and Paul M. Goodrum
  pp. 121-130 (10 pages)
  http://dx.doi.org/10.1061/41020(339)13
  Abstract | PDF (441 KB) | Permissions

In this paper, the writers present initial results of a larger study to examine the current hedonic regression model used by the Census Bureau to estimate this price index, which is used to help measure a significant proportion of the industry's real output. This study will compare the current hedonic model with a proposed model, which will include quality variables that are not part of the Census' current hedonic model. Previous research suggests that omitted quality variables in the Census' price index potentially leads to omitted variable bias which overestimates construction inflation leading to both an underestimate of construction industry output and productivity. However, previous research has not formalized

- enecessary changes to the Census index to avoid this bias nor has the bias been actually measured in order to quantify its direction or magnitude. For this paper, price and quality data of new homes was collected from Multiple Listing Service data from Warren County, Kentucky for years 2002 through 2007, which was provided by the local Board of Realtors. The data was compiled to determine the frequency of additional quality characteristics currently not measured by the Census Bureau. By identifying quality characteristics that occur at a high frequency that are also not included in the current Census index for new homes, these results serve as a starting point for further research to determine if additional quality characteristics should be included in the model.
- Measuring Construction Productivity Using the Write System Seonghoon Kim, Yong Bai, Luke Huan, and Abhinav Peddi

pp. 131-140 (10 pages) | Cited **1** time http://dx.doi.org/10.1061/41020(339)14 Abstract | PDF (2693 KB) | Permissions

To overcome the limitations of existing on-site construction productivity measurement techniques, a wireless real-time productivity measurement (WRITE) system was developed. Major components of the WRITE system include a digital camera, a video camera, a data processor, an AC transformer, a computer, and wireless modems. Researchers developed the framework of the WRITE system first. Then, a prototype of the system was built in the laboratory. Finally, the prototype system was tested for accuracy in three highway projects. Statistical analysis results proved that the developed system generated identical productivity measurements compared to the stopwatch method. The WRITE System has several unique advantages. First, there is no disruption to construction operations. Second, the on-site construction productivity can be determined in real-time so that the project manager will be able to take action immediately if necessary. Third, the collected data can be shared by all parties in the construction project via the Internet at any time and at any location. These advancements help to enhance the contractors' capability of

Construction Student Technology Skill Assessment: A Survey

Instrument
Thuy Nguyen, William O'Brien, and Kathy Schmidt
pp. 141-150 (10 pages)
http://dx.doi.org/10.1061/41020(339)15
Abstract | PDF (474 KB) | Permissions

managing construction projects.

The purpose of this paper is to describe the design and initial results of a data collection instrument developed to assess student technology skills. These baseline data are believed to be important for the educators in the construction industry to incorporate technology knowledge into the academic curricula. The instrument is a questionnaire that assesses the subject's level of technology skills in five dimensions: Attitude, Operational Skills, Interactions, Active Learning, and Cooperative Learning. Each of these dimensions has five developmental stages or maturity levels: Functional and Perceptual Knowledge, Pluralist Awareness,

Eynthetic Awareness, Competence, and Proficiency. The instrument is designed and will be validated using the Structural Equation Modeling method. The paper will present the process of initial design and data collection, the method for validation of the original instrument, and its refinement process. The original survey was distributed to 117 students in 4 Civil Engineering departments in America and initial results were used to explore the validity method of the instrument. These preliminary results and exploratory analyses suggest that with a sufficiently large sample size, it is likely that the model can be validated to satisfactorily meet the validity requirements of a well-designed measurement instrument. The data collection and validation process is still

ongoing and will be feeding the design cycle of this presumably valuable instrument.

■ 3D-GIS Based Earthwork Planning System for Productivity

Improvement
Sang Hyeok Kang, Jong Won Seo, and Kyeong Geun Baik
pp. 151-160 (10 pages)
http://dx.doi.org/10.1061/41020(339)16
Abstract | PDF (2281 KB) | Permissions

This paper proposes a GIS-based planning system for improving earthwork productivity. The system takes two planning steps considering 3-dimensional topographical conditions and other necessary information of the construction site and surroundings: 1) internal earthwork planning for earthmoving within construction site and 2) external earthwork planning for importing and exporting soil to and from construction site. Useful functions such as dissecting and grouping earth volumes for detailed task order creation, 3-dimensional analysis of haul routes, and assembling geographical and non-geographical information for equipment selection and earthwork process design are provided. Example analysis of the system is demonstrated in the paper and the analysis proves that 3-dimensional spatial manipulation and objectification of unstructured topographical data such as cut/fill mass (features) can be effectively used for earthwork planning.

Surveying Methods for Bilingual Construction Workers

Jenna Brummett and MaryEllen C. Nobe
pp. 161-170 (10 pages)
http://dx.doi.org/10.1061/41020(339)17
Abstract | PDF (440 KB) | Permissions

With a shrinking supply of workers entering the construction industry, it is vital to maintain the current workforce. As a growing source of labor, more information is needed about Spanish-speaking construction workers, including their perceptions of discrimination. The purpose of this study is to identify Spanish-speaking workers' perceptions of discrimination in the construction industry including: (a) how the language barrier has affected communication at work, (b) opportunities and obstacles for advancement, (c) compensation, and (d) overall treatment at work. Data for this mixed-method study was collected through the use of a customized survey instrument and group discussions with participants using a foreign-born interpreter. Survey data collection for Spanish-speaking individuals, however, is often difficult to

- participants using a foreign-born interpreter. Survey data collection for Spanish-speaking individuals, however, is often difficult to gather due to cultural differences that often exist between the researcher and the participants. This paper will review the survey development process for a bilingual population and surveying techniques used with this special population.
- Overtime and Productivity in Electrical Construction
- Awad S. Hanna and Gilbert Haddad
  pp. 171-180 (10 pages)
  http://dx.doi.org/10.1061/41020(339)18

### Abstract | PDF (464 KB) | Permissions

Electrical contractors are at high risk, mainly because of the high percentage of labor in electrical construction activities and the fact that a significant part of their work is last in line in a project, which leads to facing schedule compression. The main schedule compression techniques are overtime, overmanning, and second shift. This paper quantifies the impact of overtime on labor productivity for electrical contractors. Several studies have addressed overtime, but they tend to be old and the source of data is questionable. This paper contains both quantitative and qualitative analyses. The qualitative analysis is based on a survey sent to companies around the United States and Canada and analyzes contractors' responses regarding use of overtime on their projects. The quantitative analysis consists of collecting productivity data from different contractors and studying the effect of using overtime on labor productivity. Statistical models are developed and show the behavior of productivity when using overtime. The quantitative analysis further contains macro and micro approaches. The macro approach model projects where productivity for the whole project is tracked, and no specific overtime schedule is used. As for the micro approach, it shows the effect of using a fixed overtime schedule using the Measured Mile Method (MMM) which compares the productivity in unimpeded time to that in impacted time in order to determine how significantly the project's productivity was impacted. The models developed show that as the number of hours per week increases, the productivity decreases. This study will decrease disputes among owners and contractors regarding the price of additional work. Furthermore, the paper presents a scientific method for forward pricing overtime work and aiding in understanding the risks and rewards of implementing different types of overtime schedules. It also offers valuable insight with regards to safety, supervision, worker fatigue, absenteeism, and other factors related to overtime use.

Unabsorbed Overhead: Eichleay and Other Methods

Amarjit Singh and Thomas Taam
pp. 181-190 (10 pages)
http://dx.doi.org/10.1061/41020(339)19
Abstract | PDF (435 KB) | Permissions

The technique for calculation of home office overhead damages, a claim category on construction projects, has been widely debated. The Eichleay Formula is a well known technique for such claims that evolved over the past 48 years. This paper provides concepts of compensable home office overhead damage due to a project delay,

- the evolution and required prerequisites for using the Eichleay formula, and alternate formulas and techniques used. A "Direct Method" is proposed, which is simpler to apply. In the final analysis, obtaining a 100% accurate estimate of home office expenses is impractical, if not infeasible.
- Approaches for Structuring Concession Lengths and Toll Rates for Transportation Infrastructure PPPs

Martha E. Gross and Michael J. Garvin pp. 191-200 (10 pages) http://dx.doi.org/10.1061/41020(339)20 Abstract | PDF (412 KB) | Permissions

Many US transportation public-private partnerships (PPPs) are based on the concession model, under which the structure of user fees and the agreement duration is central to ensuring a fair balance of risk and reward between the public and private participants. Yet previous studies of toll-rate structuring and concession-length determination have treated these two variables largely independently. Toll charges, for instance, are typically established as either supply-based, linked to the cost of constructing, maintaining, and/or operating the facility; or demand-based, - adjusted to influence driver behavior in certain ways such as through variable time-of-day congestion charges. Concession lengths are designed separately to enable tax-depreciation advantages for the private sector and/or to mitigate traffic-demand risk. Considering these two variables together, though, provides new opportunities to improve the risk-and-reward profile for both partners. A review and comparative analysis of dual-variable approaches, illustrated by projects in which these strategies have been used, offers additional tools to consider in structuring future PPP procurements.

Analyzing the Institutional Framework for Urban Public Private

Partnerships in Indian States

<u>Ganesh A. Devkar, Ashwin Mahalingam</u>, and <u>Satyanarayana N.</u> Kalidindi

pp. 201-210 (10 pages)

http://dx.doi.org/10.1061/41020(339)21

Abstract | PDF (420 KB) | Permissions

The quality of urban engineering services such as water supply and sanitation have gradually deteriorated across India in contrast to the increasing contribution of these areas to the country's GDP. The service delivery departments of the urban local bodies (ULBs) are responsible for providing municipal services to urban residents. These departments have over the years developed and nurtured engineering competencies for the implementation of municipal projects. Now, given the deficit in urban infrastructure services, public private partnerships (PPP) are emerging as a promising model for improving municipal service delivery. From a ULBs

perspective, the implementation of PPP projects differs substantially from conventional projects since executing PPP projects requires competencies m multiple disciplines such as finance, contract law, taxation policy & regulations. The lack of capacity in ULBs to execute these complex PPP projects has subsequently emerged as a key bottleneck to the timely delivery of urban infrastructure services. The state governments in India have created institutional frameworks for facilitating PPPs in the delivery of municipal services. The state of Tamil Nadu in India has formed a nodal institution — the Tamil Nadu Urban Development Fund (TNUDF) for facilitation of PPPs in the delivery of municipal

services in Tamil Nadu. This paper analyzes several case studies of PPP projects in the urban engineering sector facilitated by TNUDF to determine the contribution made by TNUDF in effective implementation of PPP projects. Improvements in the existing institutional framework have been suggested based on lessons from the case studies and experiences of existing institutional models in other countries. Genene insights are also drawn that will help other urban governments plan and execute PPP projects better. This research contributes to knowledge at the intersection of engineering, management and policy, all of which are essential pieces in the quest to deliver basic engineering services to citizens anywhere in the world. A research agenda for the future to optimize institutional arrangements is also indicated.

Effects of the Regulatory Environment on Construction Project

Delivery Method Selection
Valerie R. Riecke Smith, Daniel Castro-Lacouture, and Rita Oberle
pp. 211-218 (8 pages)
http://dx.doi.org/10.1061/41020(339)22
Abstract | PDF (415 KB) | Permissions

The selection of an appropriate procurement system contributes significantly to the outcome of a design and Construction project. Previous research has attempted the development of a systematic approach to project delivery method selection. However, such attempts did not properly address public agencies and legislative impediments are almost entirely neglected as suggested variables in such models. This paper addresses these limitations by presenting a quantitative analysis to test whether state legal limitations do influence the selection for federal projects. Project characteristics

- From the U.S. General Services Administration Capital Construction Project database are presented. The database is analyzed using cross-tabulation to ascertain potential correlations among the variables, and specifically their relation to project delivery method choice. Contributions from this research are reflected in providing a methodology for a decision maker who is choosing among project delivery methods and is assessing the project characteristics and specifically the legislative impediments associated with a Construction project.
- Development of a Fuzzy Expert System for Surety Underwriting
   Krista Marsh and Aminah Robinson Fayek
   pp. 219-228 (10 pages) | Cited 1 time

http://dx.doi.org/10.1061/41020(339)23 Abstract | PDF (492 KB) | Permissions

In the construction industry, owners are constantly seeking practices to reduce the risk of contractor default. One method is the requirement of contractors to obtain surety bonds to bid on and

complete construction projects. Similar to contractor prequalification, there are countless factors, both quantitative and qualitative, that the surety underwriter must consider and analyze. Many of these factors are uncertain and difficult to quantify, as every contractor and every construction project is different. The purpose of this paper is to describe the development of a model to assist surety underwriters in the decision-making process of providing contractors with bonding. It incorporates two types of artificial intelligence, fuzzy logic and neural networks, to create a neuro-fuzzy expert system. By combining fuzzy logic with neural networks, the individual limitations of each can be overcome. The resulting neuro-fuzzy expert system is able to model the complex relationship between input and output variables while remaining transparent in its logic. This model is not designed to replace the experience and expert judgment of surety underwriters and brokers, but rather to verify their decisions and validate their thought processes.

Analysis of Design-Build Procurement Activities Durations for

Highway Projects
Giovanni C. Migliaccio and Pramen P. Shrestha
pp. 229-238 (10 pages)
http://dx.doi.org/10.1061/41020(339)24
Abstract | PDF (963 KB) | Permissions

The design-build (DB) method is being used at increasing rates for delivering highway projects in the United States. Benefits of adopting DB rather than the traditional design-bid-build (DBB) method have been identified by several studies that measured performance of projects delivered with DB as opposed to DBB. The majority of these studies support the widely-held belief that an owner can achieve a schedule advantage by adopting DB for delivering its projects. While these studies analyzed the duration of DB projects after a contract has been awarded, there is a lack of information on DB procurement activities' durations. This paper reports preliminary findings from a study that is collecting and analyzing data on procurement schedule durations and project characteristics to identify factors affecting duration of DB procurement and effect of duration on project success. Based on data of nineteen DB highway projects, the authors provide descriptive statistics on duration of DB procurement activities. Findings show that project size measured by contract dollar amount affects the duration of DB procurement activities. The analysis of nineteen project data shows that procurement durations had no correlation with project cost for projects costing less than \$250 million. However, when the projects costing more than \$250 million were included in the analysis, a linear correlation between these two variables existed. Future research for determining relationships between project characteristics and procurement duration as well as between procurement duration and project success is also described.

Factors Affecting Litigation Outcomes of Differing Site Conditions
(DSC) Disputes: A Logistic Regression Models (LRM)

Tarek Mahfouz and Amr Kandil

pp. 239-248 (10 pages)

http://dx.doi.org/10.1061/41020(339)25

Abstract | PDF (479 KB) | Permissions

Construction is one of the major contributing industries to the US economy. However, its advancement and contribution have always been negatively impacted by the vast number of conflicts associated with it. Traditional conflict resolution methods require legal knowledge and expertise that are not commonly available, thus cost considerable sums of money. A significant number of construction disputes could be attributed to the uncertainty in the conditions under which projects are executed, and especially site conditions. In an attempt to provide an outcome prediction system for differing site conditions (DSC) claims in the construction industry, this paper provides, as a first step, a statistical analysis of set of precedent

- eases to identify, quantify, and measure the impact of significant legal factors on outcomes prediction of litigation cases. The adopted methodology developed a statistical binary choice Logistic Regression Model (LRM) (a) to identify the effect of each legal factor on the prediction of the winning party; (b) to identify the best combination of factors with the highest prediction precision; and (c) to perform a sensitivity analysis to prioritize the most significant legal factors. Among the major findings of this paper are (1) 23 significant legal factors were identified; (2) A combination of 9 legal factors were found to attain the highest prediction precision of 93.33%; (3) Generally, cases in which the Federal Government is a concerned party, judgments are in its favor.
- Estudy of Less Than Average Bid Method
  Rita E. Awwad and Photios G. Ioannou
  pp. 249-258 (10 pages)
  http://dx.doi.org/10.1061/41020(339)26
  Abstract | PDF (465 KB) | Permissions

The low bid method is the most frequently used competitive bidding method in the construction industry. However, its main disadvantage is awarding projects to irresponsive extremely low bids which leads to disputes and claims between the owner and the contractor. To remedy this issue, some countries use the average bid method which awards the job to the contractor who submits the closest bid to the average of all submitted bids. A comparison between Friedman's low bid method and the average bid method was conducted by Ioannou and Leu (1993), and showed mat although the average bid method protects the owner against extremely low bids, it does not promote fierce competition as is the

- extremely low bids, it does not promote fierce competition as is the case in a low bid awarding system. Thus, they suggested another variation of the average bid method which is awarding the job to the contractor whose price is closest to but lower than the average of all submitted bids. This paper uses Monte Carlo simulation to model the less than average bidding method. It explores its merits relative to the other two bidding methods, and proves it to be a compromising middle ground between the low bid method and the regular average bid method.
- Investigation of Supply Chain Management Practices in Industrial
- Projects: State of Practice vs. State of Knowledge
  Marcelo M. Azambuja and William J. O'Brien

pp. 259-268 (10 pages) http://dx.doi.org/10.1061/41020(339)27 Abstract | PDF (414 KB) | Permissions

This paper focuses on strategic sourcing and planning issues and describes a set of supply chain practices implemented by leading EPC firms and owners executing industrial projects worldwide. Industrial projects include suppliers who are located overseas, a major part of installed items are long lead engineered equipment, shop fabrication capacity is limited and their prices are escalating. Our main purpose is to contrast current practices against the ones presented in the current body of knowledge. The authors conducted interviews with experienced Procurement and Materials Management managers and analyzed documents supporting supply decisions. This study provides an up-to-date description on how firms have been mitigating material supply risks in such complex environment via supplier integration, relationships, supply chain planning, and use of market knowledge information.

- A New Approach to Contracting Design Professionals

  John K Michael Brad D Carey and Kenneth T Sulliv
- John K. Michael, Brad D. Carey, and Kenneth T. Sullivan pp. 269-278 (10 pages)
  <a href="http://dx.doi.org/10.1061/41020(339)28">http://dx.doi.org/10.1061/41020(339)28</a>
  Abstract | PDF (434 KB) | Permissions

In a recent survey of clients and buyers of Construction, the Construction Management Association of America (CMAA) found mat over 50% of design efforts finish behind or significantly behind schedule. Furthermore it found that 70% of clients have seen the quality of design documents decrease over the past ten years with 97% of clients agreeing that designers should be held more accountable for the quality of the designs that are delivered. This paper presents the research results of applying a new approach to contracting design professionals that enforces accountability and minimizes risk through the adaptation of six sigms and lean

minimizes risk through the adaptation of six sigma and lean principles. The new approach theorizes that the inefficiencies in the design industry are due to the selection and contract management system used by most clients. The first 39 design project test results are presented in the paper, along with the evolution of the design delivery model. Key finding include the threat of political risk to change, the inability of most design professional to address specific project risk, and the lack of preplanning evident in most design projects.

- Mapping the Value Thread in Local Government Service Delivery
- in South Africa
  C. I. Jay, P. A. Bowen, and K. S. Cattell
  pp. 279-287 (9 pages)
  http://dx.doi.org/10.1061/41020(339)29
  Abstract | PDF (462 KB) | Permissions
  - A framework for understanding public sector decision-making in relation to projects, programmes and policy is presented. The framework builds on Value Management (VM) theory by adding a

component to the classical VM model. The framework demonstrates that, apart from the functional value of alternative materials and their costs, a choice of one particular technical solution also requires consideration of moral issues. The model is illustrated within the context of housing policy in South Africa. The paper concludes by examining some published measures of project success and indicates that more work is needed to establish what constitutes real value add in project delivery in this sector.

- How Far a Contract Can Be Stretched? The First Building Block
- for Procurement Engineering
  Chen-Yu Chang
  pp. 288-297 (10 pages)
  http://dx.doi.org/10.1061/41020(339)30
  Abstract | PDF (444 KB) | Permissions

This research is a first attempt to develop the new research field of Procurement Engineering. Just as Earthquake Engineering can instruct us how to design a building in order to mitigate the damages caused by natural uncertainty, Procurement Engineering hopes to offer methods to design project governance in order to reduce the adverse impacts of risk on projects. Just as Earthquake Engineering is founded on the basic law of mechanics that can precisely describe the movement of structural components under - different loading conditions, Procurement Engineering needs to develop a fundamental law that governs the interaction between the procurer and the contractor in the face of uncertainty. This research aims to answer this call by first defining the risk-bearing capability of project governance, and second developing a mathematical equation for its measurement. The formal modeling of this concept can inform the design of project governance by integrating contract form, payment mechanism, financing structure of the contractor and choice of procurement systems into a logical coherent framework.

- Exploring the Learning Styles of the Construction Practitioners in
- Hong Kong
  Peter S. P. Wong, Sai On Cheung, and Wally S. W. Lai
  pp. 298-307 (10 pages)
  http://dx.doi.org/10.1061/41020(339)31
  Abstract | PDF (471 KB) | Permissions

There has been strong advocate that through effective interorganizational learning (inter-OL), construction project efficiency and effectiveness can be improved. In this regard, some researchers recommended exploring the possible ways to facilitate inter-OL. It has been suggested that project team members may have different learning styles that shape how they imbibe knowledge,

communicate, solve problems and make decisions. Through understanding the learning styles, members can realize each others' strengths and weaknesses in learning. Thus, appropriate strategies can be adopted for facilitating others' learning. Some researchers have used the Learning Style Questionnaire (LSQ) developed by Honey and Mumford (1982) to measure the learning styles of the individuals. Nevertheless, the reliability of the LSQ in measuring

the learning styles of the project team members has yet been examined. This paper reports a study that aims to examine the use of the LSQ in identifying the learning styles of members from two types of firms: the contractor firms and the consultant firms. Data were obtained from a questionnaire survey in Hong Kong and were analyzed by using Cronbach alphas reliability testing, Pearson correlation Analysis and Analysis of Variance. The results suggested that LSQ is reliable in identifying the learning styles of the respondents. Furthermore, the respondents from the consultant firms are found to be flexible in adopting different learning styles to grasp experience and transform it to knowledge. In contrast, respondents from the contractor firms are oriented towards a Reflector learning style when transforming experience to knowledge. This suggests that longer time is needed when actions are required to be taken in response to environmental change.

Integrating Uncertainty Management in Strategic Planning Practice

Despite competing in highly turbulent and competitive industry,

Robby Soetanto and Andrew R. J. Dainty
pp. 309-219
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Abstract | PDF (924 KB) | Permissions

evidence suggests that construction firms have not put sufficient emphasis on strategic planning. Further, the practice of strategic planning in construction is dominated by informal and sporadic approaches/ processes, which rely heavily on the subjective judgement of top management and tacit knowledge of individuals involved. Literature indicates that the identification of possible risks and opportunities is the most critical in this process, but little guidance is available with regards to the most effective approaches in dealing with the inherent characteristics of strategic planning. A review of underlying aspects (including decision theory, cognitive and behavioural psychology) is presented with a view of developing a framework for improving this process in a construction firm. The framework attempts to engage stakeholders and capture both explicit and tacit knowledge in the strategic thinking for organisational learning. The framework is viewed as a better alternative to the top-down approach of strategic decision making in the construction industry. Benefits from adopting such an approach and future direction of research in this area are then

- The Last Decade Analysis and the Near Future Trends in
- International Construction
  Suat Gunhan
  pp. 320-329 (10 pages)
  http://dx.doi.org/10.1061/41020(339)33
  Abstract | PDF (431 KB) | Permissions

discussed.

The worldwide decrease of international construction activities starting from 1997 Asian crisis, started to gain momentum in 2002, and continues to grow parallel to world economic expansion. The paper analyzes the international construction sector within the 1997

-2007 periods. It makes the world regional and the respective construction firms' analyses within the context of major trends such as firm acquisitions, facilities management, infrastructure projects, and public private partnership delivery systems. The paper suggests strategies and predicts the near future while highlighting the available threats and opportunities in international construction. Concluding remarks highlight that the most of the markets will continue to be attractive. China, Russia, Middle East and Eastern Europe are expected to be the leading markets although terrorist activity concerns exist in the Middle East. The trends such as the application of more innovative project delivery systems, increase in sustainability, and establishment of global professional and enterprise licensing are highlighted.

Beyond Sustainability: The Contractor's Role in Regenerative

System Design
Rebecca Mirsky and Anthony D. Songer
pp. 330-337 (8 pages)
http://dx.doi.org/10.1061/41020(339)34
Abstract | PDF (431 KB) | Permissions

line to integrate three aspects of sustainability into the organizational process: economic growth, environmental protection and social equity. This concept is evolving toward a regenerative design approach that promotes a triple "top" line, moving accountability to the beginning of the design process by assigning value to a variety of economic, environmental and social factors. There, is an increasingly important need for proactive participation - from the construction community in this new generation of sustainability efforts. Otherwise, there will be a widening gap between design and construction, in which the contractor role in sustainability is marginalized, relegated to merely minimizing endof-project impacts rather than adding value and innovation throughout the project. This paper examines the triple top line in the context of construction projects and identifies opportunities for construction professionals to play a collaborative role in developing the next generation of regenerative facilities.

Current business models employ the concept of the triple bottom

Acquiring Local Knowledge for International Projects

Amy Javernick-Will and Raymond Levitt

pp. 338-349 (12 pages)

http://dx.doi.org/10.1061/41020(339)35

Abstract | PDF (486 KB) | Permissions

The construction market offers numerous opportunities for firms seeking to expand internationally. One can witness the amazing growth of "mega-cities" firsthand by observing skies filled with cranes in the Middle East, China, and other resource-rich

developing countries. Projections for future demand in infrastructure and the built environment indicate that there will be increasing demands for firms to engage in projects around the world. There are tremendous opportunities for firms in the international construction market, but international construction

projects also face numerous uncertainties and risks. These projects bring together teams working in unfamiliar environments with differing regulations, norms and cultural beliefs, which can lead to increased misunderstandings and costs. A key strategy that successful global firms adopt to reduce these costs is to increase their capabilities for acquiring and sharing information and knowledge about each local environment in which they have worked to use on their portfolio of international projects. This study compiles and analyzes data from 15 case studies of international firms engaged in global infrastructure development to identify the types of local and regional knowledge managers perceive to be most important to the success of their international projects. The firms covered in the case studies are of three types: real estate developers, contractors and engineers. These three firm types have different responsibilities and are involved in different phases of the project lifecycle. The paper concludes with the different kinds of knowledge that each firm type finds most critical to acquire and share in order to enhance the success of their global projects.

Investigation and Modeling of Critical Success Factors in **Construction Organizations** 

Emad Elwakil, Mohammad Ammar, Tarek Zayed, Muhammad Mahmoud, Ahmed Eweda, and Ibarhim Mashhour pp. 350-359 (10 pages)

http://dx.doi.org/10.1061/41020(339)36 Abstract | PDF (424 KB) | Permissions

Profit and success are considered the main drivers of any organization. Achieving this success is based on many factors which have a direct effect on the performance of these organizations. Predicting construction organizations performance helps define the weak organization points in order to improve its performance and increase the profit. In construction organizations, it is more difficult to achieve or maintain a scientific strategy to measure their current success due to the diversity and complexity of construction organizations. Previous studies used questionnaires and interviews with technical and professional persons. However, most of these studies concentrated on the critical success factors on project level. The scope of this study is to investigate the most significant organizational success factors with focus on

construction organizations. This paper aims at determining most significant (i.e. critical) success factors, and to develop a model to predict the company performance based on these critical success factors. The potential success factors were surveyed from the literature study. A questionnaire was prepared for evaluating the effect of those potential success factors on organizational performance. The data collected were analyzed using Artificial Neural Networks (ANNs). Neuro-Shell software was used to rank the potential success factors utilizing the data obtained from different construction organizations. The critical success factors were used in-turn to develop a NN prediction performance model of construction organizations. The model can be used to predict the performance of a construction organization based on estimated values of its success factors.

Use of A3 Reports to Focus Design and Construction

© Conversations

Kristen Parrish, Iris D. Tommelein, and Glenn Ballard pp. 360-369 (10 pages)

http://dx.doi.org/10.1061/41020(339)37 Abstract | PDF (861 KB) | Permissions

This paper describes a project team's use of A3 reports to focus their conversations and direct their decision-making process throughout the design phase of a hospital project. A3s are named after the size of the paper they are presented on (approximately 11" x 17") and provide a concise description of options and tradeoffs associated with a given problem or decision. A3s are widely used at Toyota as conversation pieces and to document steps of the Plan-Do-Check-Act (PDCA) cycle that supports their continuous

improvement process. A3s combined with use of an integrated form of agreement (IFOA) promote the creation of shared understanding of various design options and associated design impacts, and thus support set-based design. This paper presents the development and use of an A3 report related to selection of a landscape architecture consultant. Research on this case study indicates A3 report detailing must advance in parallel to design development; otherwise, insufficient detail is available to facilitate `real time' decision making.

Creating Organizational Change: Minimizing Client Generated
Construction Inefficiencies at the US Army Medical Command
Jacob S. Kashiwagi, Neha Malhotra, Eduardo Luna, Dean T.
Kashiwagi, and Kenneth T. Sullivan
pp. 370-379 (10 pages)
http://dx.doi.org/10.1061/41020(339)38
Abstract | PDF (434 KB) | Permissions

The United States Army Corps of Engineers (COE) and Army Medical Command (MEDCOM) work in tandem to meet the hospital construction requirements for military bases located across the country. Over the past three years, MEDCOM has partnered with the authors to increase the efficiency of their construction delivery system through the research and testing of a new performance information environment. The objective of the research is to create an organizational structure and performance reporting platform that minimizes the need for decision making by

environment can generate clear, timely, accurate, and dominant information, the need for decisions will be reduced, as the data will drive organizational operations and become self-regulatory. To date, the information has allowed an increase of contract performance from an average of 25% on-time and on-budget, to a current average of 40% on-time and 67% on-budget. This paper documents the hurdles and impacts, based upon a three year research effort, of implementing an automated technology for collecting and tabulating performance metrics, to create and sustain an information environment. Past literature has also shown that

some 80% of organization change fails, the key finding of this paper is that performance information can be used to drive organization change and culture adjustment to create a sustained efficiency improvement in a large bureaucratic entity.

How to Determine Construction Project Rain Delay Times Using

Local Rainfall Databases in Asheville, NC
George Ford, John Patterson, and Bradford Sims
pp. 380-385 (6 pages)
http://dx.doi.org/10.1061/41020(339)39
Abstract | PDF (408 KB) | Permissions

Rain delays can prove costly to construction contractors and significantly affect long-term profitability if not carefully considered during the planning stages of a project. This paper includes a short literature review of technology related to predicting construction project rain delays and an analysis of rainfall event probabilities for the Asheville, North Carolina region. An analysis methodology is provided in a step-by-step discussion which illustrates how to determine statistical probabilities of significant rainfall events to forecast construction project delays. Local rainfall data for Asheville, NC is analyzed to determine rainfall frequency to provide an example of the forecasting methodology for the reader.

Integrated Module for Mobile Crane Dynamic Instability Analysisand Supporting System Design

<u>Shafiul Hasan</u>, <u>Mohamed Al-Hussein</u>, <u>U. H. Hermann</u>, and <u>Hassan Safouhi</u>

pp. 386-395 (10 pages)

http://dx.doi.org/10.1061/41020(339)40

Abstract | PDF (984 KB) | Permissions

Stability is an important safety issues related to the use of mobile cranes. Dynamic loading related to crane motion and load are the key factors associated with the failure to maintain stability. In this regard, the dynamic nature of mobile crane operations entails a variety of outrigger reaction values for truck cranes and track pressure values for crawler cranes. Crane supporting reaction or pressure is a function of the lifting configuration, crane geometry, and the crane component's weight; in most situations, such information is not readily available. Moreover, this paper presents an algorithm which is designed to assist practitioners in evaluating the elements required for calculating the reaction forces for both types of mobile cranes—truck cranes on outriggers and crawler cranes on tracks—and checking the stability of the crane. The developed algorithm integrates a reaction influence chart, which accounts for the dynamic relationship between the reaction of the outriggers or pressure of the crawler tracks and the boom's horizontal swinging and vertical angles. The developed algorithm is also integrated with a previously developed crane selection system and a database. Finally, a case example is described in order to demonstrate the use of the presented algorithm. The proposed

system has proven to be effective in reducing the time and cost associated with the preparation of lift studies.

The Realities of Building Information Modeling for Collaboration

in the AEC Industry
Carrie S. Dossick, Gina Neff, and Hoda Homayouni
pp. 396-405 (10 pages)
http://dx.doi.org/10.1061/41020(339)41
Abstract | PDF (439 KB) | Permissions

In this paper, we will report on how the introduction of a new technology, Building Information Models (BIM), is in the process of changing collaboration among architects, engineers, and builders. Using a multi-method study of comparative case studies and triangulation interviews, we have observed two building projects over an eight-month period, interviewed architects, engineers, general contractors and subcontractors, and we are able to create generalizable grounded theory about technology-supported collaboration. This rich ethnographic data enables the analysis of the ramifications of the existing frameworks of standards of practice and occupational boundaries for collaboration, and allowed us to identify the potential of new technology to change these frameworks. Technology is always embedded in a social context,

- us to identify the potential of new technology to change these frameworks. Technology is always embedded in a social context, and its successful adoption depends upon that context. Some in the building design and construction industry are pushing for new technological advancements along side collaborative delivery methods, but there remain a number of organizational questions that must be addressed, particularly in how to engage second and third tier consultants, suppliers and subconstructors who are not part of the primary architect-owner-contractor agreements. Where delivery methods alone will not address the inter-organizational challenges, strategies such as co-location support a stronger team orientation to the project through informal communication.
- Virtual Construction Automation for Modular Assembly Operations
   Jacek Olearczyk, Mohamed Al-Hussein, Ahmed Bouferguene, and Avi Telyas

pp. 406-415 (10 pages) http://dx.doi.org/10.1061/41020(339)42 Abstract | PDF (1533 KB) | Permissions

On large construction sites crane positions tend to be determined through a process of trial and error. The analysis of complicated spatial static equipment locations is not an easy task. It requires understanding of many complicated aspects of not only the lift procedures or crane equipment limitation but also knowledge of the lifted objects. The virtual, an three-dimensional (3D) CAD

modeling process allow for the storage, not only of shape and color (visual aspect), but also material properties, and parametric dependency (intelligent aspect). The utilization of advanced CAD tools allows for the exploration of the behavior of a structure. Digitally animated and simulated, modular construction assembly operation illustrate benefits of implementing 3D and 4D modeling for analysis of lifts and sequence optimization. This paper provides

an example of development and methodology to optimize crane selection operation process for the onsite erection of five, three stories dormitory buildings in McGregor Village for Muhlenberg College in Allentown, Pennsylvania USA. Fully habitually modular assembly units were delivered securely on flatbed trailers in advance to the site. A 600 Tone mobile hydraulic crane was placed in the center of construction site to lift over 100 modules in order to construct the 5 buildings in only 10 working days. Created CAD models were efficiently utilized to optimize detailed schedule. The process includes the creation of kinematic movement for each module lift then simulation sequences and finally compile AVI video movie for review and approval.

Identification of Data Items Needed for Automatic Clash Detection
 in MEP Design Coordination

Fernanda Leite, Burcu Akinci, and James Garrett, Jr. pp. 416-425 (10 pages) | Cited 1 time http://dx.doi.org/10.1061/41020(339)43
Abstract | PDF (477 KB) | Permissions

This paper discusses a study carried out during the mechanical, electrical and plumbing (MEP) design coordination of a 210,000 square feet facility, currently under construction in Western Pennsylvania (Project X). We have compared types of clashes identified in their manual coordination process (overlay of 2D drawings on a light table by pairs of subcontractors) and through automatic clash detection using a building information model (BIM) in NavisWorks JetStream v5. The automatic clash detection identified several clashes that were missed by the subcontractors, who were performing this task manually. Also, the manual clash detection identified clashes which could not possibly be found by the automatic clash detection software, since one of the clashing objects (e.g. cable trays) was not modeled in the BIM. This study also included site observations of field detected clashes, some of which were not identified in either manual or automatic processes. Results show that the combination of clashes identified in coordination meetings, those automatically detected, as well as those identified in the field enable identification of objects that need to be modeled in order to capture the largest possible number of clashes. This paper was limited to the comparison of types of clashes identified in each of the three methods during a specific project. Although these results cannot be generalized, they still provide insight towards the need to identify what needs to be modeled in a BIM for MEP coordination prior to the start of the coordination process.

Early Design Energy Analysis Using BIMs (Building Information Models)

Annette Stumpf, Hyunjoo Kim, and Elisabeth Jenicek pp. 426-436 (11 pages) http://dx.doi.org/10.1061/41020(339)44
Abstract | PDF (1142 KB) | Permissions

An emerging area of interest within the A/E/C industry is designing sustainable buildings, as evidenced by the increasing use of the US Green Building Council (USGBC) LEED® (Leadership in Energy and Environmental Design) green building rating system. This research utilized Building Information Modeling (BIM) for energy analysis during the conceptual design phase. Most building energy analyses are conducted late in the design by energy analysts. This paper describes a process of exploring different energy saving alternatives in early design using 3D-CAD (computer aided design)/BIM technology. The recommended process allows project

- teams to utilize BIM models in energy simulations and compare results quickly. In order to test the feasibility of the proposed approach, a prototype energy modeling process was developed and tested on a new construction project, the Community Emergency Service Station at Fort Bragg, North Carolina with a team led by the U.S. Army Corps of Engineers. The energy modeling process was applied to explore different building envelope and equipment scenarios to enable energy conscious decisions early in the design process when they make the biggest impact on building life cycle costs.
- Improving Site Utilization Planning through the Use of Interactive
  Workspaces
  - Robert M. Leicht and John I. Messner pp. 437-446 (10 pages)
    http://dx.doi.org/10.1061/41020(339)45
    Abstract | PDF (586 KB) | Permissions

In ongoing research into the value of Interactive Workspaces for improving team collaboration, this paper reports on the value demonstrated for different forms of interaction while teams performed site utilization planning designs. Interactive workspaces are spaces with potential for ubiquitous electronic interaction to allow for enhanced communication and capture of information. In the experiment reported, 24 groups of students with typically 4 group members were asked to perform site utilization planning for three phases of the Long and Foster Headquarters project in Chantilly, VA. The focus of the study was to identify changes in the students' interactions when using the space, and the difference

when different forms of software and display interaction were introduced. The change in the team communication is based on the number of students with easy access to shared visual information. The teams were provided with either tablet PC's, one per student, or a single interactive whiteboard to sketch the schematic design of the site as they developed their plans. Students typically found the use of the interactive whiteboard to provide a more collaborative environment than using tablet PC's, but at the same time value in utilizing multiple displays with the parallel interaction using the tablets. All teams found working in the interactive workspace more enjoyable than typical meetings and would be interested in using the space for similar tasks in the future.

- Nanotechnology: Benefits, Barriers, and Impact on Construction
- Manu Venugopal, Jochen Teizer, and Winfried Teizer
  pp. 447-456 (10 pages)
  http://dx.doi.org/10.1061/41020(339)46
  Abstract | PDF (818 KB) | Permissions

Nanotechnology research and product development is actively conducted in many industries, for example, in manufacturing, electronics, and health sectors. As many research studies show, the construction industry follows these trends, but does not take a leadership role in most of the current efforts in Nanotechnology. With proper knowledge about the products and techniques offered by nanotechnology, the construction industry has the potential to improve the efficiency of some of its own processes and offer better products to customers and clients. This research tries to understand

- nanotechnology in the context of construction and explores the current scenario of nanotechnology in the construction industry. In order to identify the potential benefits and existing barriers, an extensive literature review and survey were conducted, which is supplemented by several personal interviews. This paper also performed an impact analysis to evaluate existing and developing nanotechnology products and their applications in construction. Recommendations and guidelines for a path forward for nanotechnology in construction industry are provided.
- Ontology-Based, Semi-Automatic Framework for Storing and Retrieving On-Site Construction Problem Information An RFID-Based Case Study

  Tarek Elghamrawy, Frank Boukamp, and Ho-Sung Kim pp. 457-466 (10 pages)

  http://dx.doi.org/10.1061/41020(339)47

  Abstract | PDF (2109 KB) | Permissions

Construction projects are information-intensive. Quick information retrieval and correct information capturing on construction sites is important to support project management. This paper presents the prototype of a semi-automatic framework for storing and retrieving on-site construction problem information using context information. Created problem records are indexed with context concepts taken from developed Web Ontology Language (OWL)-based ontologies, which enable semantic searches through problem

- erecords. However, since selecting appropriate concepts from large sets of concepts defined in the ontologies can be cumbersome, the prototype offers capturing context concept information automatically through the use of Radio Frequency Identification (RFID). A Java-based reasoning mechanism has been developed to support the user by inferring other applicable and related concepts based on the automatically identified and selected ones. The framework is described in this paper, including findings obtained from a case study and challenges identified.
- Building Information Model: The Role and Need of the
- © Constructors
  Pooyan Aslani, F. H. (Bud) Griffis, and Lawrence Chiarelli

pp. 467-476 (10 pages) http://dx.doi.org/10.1061/41020(339)48 Abstract | PDF (985 KB) | Permissions

Much of the discussion thus far associated with the employment of building information modeling (BIM) has focused on the design phase; the preparation of the model by the designers, "ownership" of the model, and liability for others' use of and reliance on the model. The first generation of BIM employed by constructors involved the creation of a three-dimensional model based upon the two-dimensional drawings prepared by the designers. One of the greatly touted advantages of the next generation of BIM is the creation of a single model for the project to which the designers, constructors and owners will contribute. The manner in which the model is generated and the additional information associated with the model, however, will impact the utility of the model for the designers, constructors and owners. The functions for which BIM will be most beneficial to constructors include the preparation of schedules and estimates, tracking and managing changes to the work and shop drawings, and managing site logistics and temporary structures and services, with particular attention to site safety. The purpose of this paper is to identify the constructor's requirements for the preparation of a building information model during the design phase so as to most efficiently address the concerns of the designers, constructors and owners. In addition, the paper will examine the processes employed by constructors in the management of the construction project.

Developing Construction Network-Based Interface Management

System

Yu-Cheng Lin

pp. 477-486 (10 pages)

http://dx.doi.org/10.1061/41020(339)49

Abstract | PDF (463 KB) | Permissions

It is necessary to trace and control related interface events and problems in construction management. Interface management (IM) approach play an important role in construction management. The interface events can be identified and traced in interface management for involved participants to improve the construction process and minimize deleterious change. This study proposes a new and practical methodology to track and manage interface events by using network-based maps. Using network-based maps, users can get an overview of previous and current interface events

in selected project and take appropriate advanced control and manage interfaces and problems in construction building project. This study addresses application of interface management in construction/mechanical/electrical of building project and proposes a Construction Network-based Interface Management (CNIM) system for project participants. The CNIM system is will applied in selected case study of a building project in Taiwan to verify our proposed methodology and demonstrate the effectiveness of interface management. The main purpose of this study is to developing a web-based interface management system for involved

engineers to increase interface event information sharing and tracing efficiency. Project managers and engineers can take advantage of interface events information flow to help managers and engineers to handle interface events and activities through CNIM system. By effectively using network-based maps and web technologies during the construction phase of a project, interface management can be enhanced and improved in build projects.

- Virtual Supervision in Construction Projects
- Lahiru P. Silva, Janaka Y. Ruwanpura, and Kasun N. Hewage pp. 487-496 (10 pages)
  <a href="http://dx.doi.org/10.1061/41020(339)50">http://dx.doi.org/10.1061/41020(339)50</a>
  Abstract | PDF (948 KB) | Permissions

Better utilization of supervision time is a key factor to improve communication in construction projects. Popularity of the remotely accessed cameras in construction industry has increased drastically in the last few years. The concept proposed in this paper is an information management and a supervision time optimization system called "Virtual Supervision" model. This model enables the supervisors and other stakeholders of a project to monitor construction activities remotely and address the issues by using a surveillance camera system integrated with a few other technological tools. The focus of the "Virtual Supervision" model is to improve the efficiency, communication, and worker satisfaction. The system facilitates efficient information flow between the site office, site, head office, and other relevant stakeholders.

- 3D Work Environment Modeling for the Intelligent Excavation
- System (IES)
  M. Chae, G. Lee, J. Park, J. Kim, and M. Chopp. 497-505 (9 pages)
  <a href="http://dx.doi.org/10.1061/41020(339)51">http://dx.doi.org/10.1061/41020(339)51</a>
  Abstract | PDF (909 KB) | Permissions

This paper presents a new method of real-time earth surveying using 3D laser scanner (3D imaging system) and the development of a customized software and a method for automatic data processing. Authors of this paper participate in the Intelligent Excavation System (IES) development project, which includes the development of technologies for surveying of earth environment and controlling unmanned excavator. This paper describes 3D earth work environment modelling part of the IES project. 3D laser scanner loaded on a mini-van scans the earth work area repeatedly to monitor the changes while earth work is done by excavators and loaders. Algorithm of registering (stitching) multiple scan segments into one 3D model on a common 3D coordination has been developed. Through a several experiments, important issues in 3D earth modelling have been found.

- Querying IFC-Based Building Information Models to Support
- Construction Management Functions
  M. P. Nepal, J. Zhang, A. Webster, S. Staub-French, R. Pottinger, and M. Lawrence

pp. 506-515 (10 pages) http://dx.doi.org/10.1061/41020(339)52 Abstract | PDF (2224 KB) | Permissions

The design and construction community has shown increasing interest in adopting Building Information Models (BIM). While the richness of design information offered by BIM is evident, there are still tremendous challenges in getting construction-specific information out of BIM, particularly from IFC-based product models. This paper describes our approach for querying construction-specific design conditions from an IFC-based model. The approach involves: (1) the formalization of constructionspecific design conditions as an ontology of product features, (2) the automated generation of feature-based product models for a particular construction domain and function, and (3) a formal specification that supports user-driven queries of the feature-based model. This approach allows practitioners to answer a broad range of user-customizable queries in support of different construction management functions. It also transforms designer-focused EFCbased models into construction-focused, feature-based models.

Advanced Quality Control Methods for Road Paving Construction

by Utilizing Sensory Devices
Yong K. Cho, Thaddaeus Bode, and Yong-Rak Kim
pp. 516-525 (10 pages)
http://dx.doi.org/10.1061/41020(339)53
Abstract | PDF (2127 KB) | Permissions

This study is currently being conducted to produce a more realistic picture of how variables are created and dealt with from hot mix asphalt (HMA) paving construction in the State of Nebraska. Several paving projects across Nebraska have been visited where sensory devices are being used to test how density, moisture content within the asphalt, material surface temperature, internal temperature, wind speed, haul time, and equipment type, contribute to temperature differentials. Areas of high temperature differentials - are identified using an infrared camera, and confirmed with a penetrating thermometer. A non-nuclear density device is also used to record how the lower temperature asphalt density compares to the more consistent hot area. After all variables are recorded, the location is recorded via a handheld global positioning system (GPS) to aid in locating points of interest in future site revisits to verify the research findings. Initial data collection suggests that most variables having the largest impact on quality can be controlled with adequate planning, and proper lay down procedures.

Embodied Energy of CDW Recycling and Technical Metabolism

Due to Regional Differences and Building Designs

Christopher Hermreck and Wai K. (Oswald) Chong

pp. 526-536 (11 pages) | Cited 1 time

http://dx.doi.org/10.1061/41020(339)54

Abstract | PDF (431 KB) | Permissions

Energy and resource efficiencies are both critical to achieve building design and construction sustainability. Embodied energy measures the energy needed to produce, install and maintain materials while technical metabolism enhances building design recyclability. Although the concepts of embodied energy and technical metabolism have been around for many years now, the measurement systems for embodied energy and recyclability are still unreliable. Four projects were selected and the energy use the recycled materials from these projects were thoroughly examined. Past researches were also investigated. The study found that the embodied energy and recyclability were affected by several critical

- efactors, such as, distances between project site and the locations of recycling facilities, regional variables and conditions, social preferences, and design complexities. The study also concluded several critical imperfections in the existing sustainability tools, such as the calculation of embodied energy, and the implementation of technical metabolism. The authors propose a framework to capture accurate information on embodied energy and resource efficiency to better reflect the "true" sustainability and greenness of building designs and construction. However, the authors also acknowledge that more works need to be done in this area to allow engineers better understand and acknowledge the real energy and resource consumptions of their designs.
- A Proposed Eco-Labeling Method for Building Design
  Joseph Rendall and Wai K. (Oswald) Chong
  pp. 537-547 (11 pages)
  http://dx.doi.org/10.1061/41020(339)55
  Abstract | PDF (418 KB) | Permissions

Buildings consume nearly 40% of all energy use and building construction and demolition generate huge amount of pollutants and wastes. Consequently, buildings and building products need to be more eco-friendly in order to minimize the impact to the environment. Eco-efficiency is one of the many concepts that designers can apply to reduce the environmental impact of designs. Several public agencies and private companies also offer a variety of ecolabels that validate the ecoefficiency of project, company,

- esystem or material. The research team integrates the concept of ecoefficiency with food labeling technique to develop a new ecolabeling concept that could potentially improve the communication of building eco-efficiency information at the design stage. The paper also discusses the potential hindrances and conflicts of the proposed ecolabel. The intention of this ecolabel is to convey the information of building design and product ecoefficiency accurately to the designers so that they could reduce the impact of their designs on the environment.
- A Decision-Making Framework to Assess Stakeholder Value in
  Adoption of Sustainable Practices in Construction
  Amlan Mukherjee and Helen Muga
  pp. 548-557 (10 pages)
  http://dx.doi.org/10.1061/41020(339)56

### Abstract | PDF (511 KB) | Permissions

The significant environmental impact of the construction industry, its critical role in the economy, and the urgent need to respond to global climate change has created economic and environmental challenges that the architecture, engineering and construction (AEC) industry is increasingly encountering. The diversity of priorities and differing perceptions of risk about the adoption of green building practices among industry stakeholders is critically shaping the adoption of green technology, and the rate at which the industry is shifting towards more sustainable practices. In this paper, we develop an integrated framework that uses a probabilistic definition of value to integrate reductionist methods of sustainable decision-making, within a complex adaptive systems definition of the context within which such decisions are made. It is founded in probabilistic risk assessment and system dynamics, and is used to aid individual adoption of sustainable technology and study its diffusion through professional networks in the AEC industry.

- Key Attributes of a Longitudinal Study of Green Project Delivery
   Sinem Korkmaz, Michael Horman, and David Riley
  - pp. 558-567 (10 pages) | Cited **1** time http://dx.doi.org/10.1061/41020(339)57 Abstract | PDF (466 KB) | Permissions

If green buildings are to continue to reduce the environmental impact of buildings and improve the operating performance of facilities, it is now more important than ever that a study of key project delivery practices, like teaming strategies, contracting approaches, and incentives, be established for these projects. When the performance outcomes of these projects, like sustainable rating, final cost, project schedule and operating performance, are statistically correlated to the project delivery practices, tremendous insight is gained for owners on how to establish their team so that their performance objectives are maximized on their green project. Initial exploratory research reported in this paper confirms how

- e scientifically challenging such a study is to pursue with rigor. There are so many potential variables that may impact sustainable performance outcomes that a quality study needs a sample size in the thousands. By necessity a large study must occur over many years and thus the design of the study is crucial due to the time that lapses between implementation and results. This type of study, often referenced as a longitudinal study, is common in more mature disciplines of anthropology and medicine, especially, epidemiology. The contributions of the paper include a set of preliminary project delivery attributes to focus on for green building projects and data collection and analysis methods for large study of green building project delivery.
- Performance Testing of an Integrated Solar Collector System
- Marwa Hassan and Yvan Beliveau
  pp. 568-577 (10 pages)
  http://dx.doi.org/10.1061/41020(339)58
  Abstract | PDF (2267 KB) | Permissions

Due to the up-front costs of add-on solar collection systems, the cost-effectiveness of solar energy is still in doubt. Building integrated solar thermal systems may improve the cost-effectiveness of add-on collection systems given their ability to expand to cover the entire area of the roof at a reasonable cost. The objective of this study was to evaluate the effectiveness of a newly-developed flat-plate integrated solar collector system. The developed collector system consists of a low temperature flat plate collector integrated within a concrete building envelope. To evaluate this system, a full-scale test prototype of the solar collector was constructed and instrumented with thermocouples.

- Measurements were conducted over a 7-month period in which the solar collector was evaluated over different climatic conditions. Based on the results of the experimental program, it was determined that the solar collector provided an efficiency ranging from 49 to 75% in the range of ambient temperature, solar radiation, and inlet temperature evaluated in this experiment. The estimated efficiency of the system was on the high range as compared to the reported efficiency of similar systems. Depending on the extent of the collection area, the developed solar collector can provide a significant portion of the building's space heating and hot water needs especially in the spring and summer seasons.
- Incentives for Green Residential Construction
- Michael Sauer and Khalid Siddiqi
  pp. 578-587 (10 pages)
  http://dx.doi.org/10.1061/41020(339)59
  Abstract | PDF (457 KB) | Permissions

The objective of the study was to benchmark the relationship between municipal incentives and actual production of LEED certified multi-unit residential buildings in the US. The incentives include financial incentive, density bonus and administrative incentives provided for green projects by the local government institutions. The study conducted was based on the population of LEED certified multi-unit residential buildings in the U.S. A comparison of the regional project distribution with applicable

municipal incentives enabled formulation of a correlation coefficient between the incentive and the number of LEED certified multi-unit residential projects developed in the US. Major finding from the study was that LEED certified multi-unit residential development was significantly higher in areas where incentives were made available to developers versus those where they were not. *Density Bonus* incentive, where available, was determined to be the main cause for higher production of LEED certified multi unit residential buildings in a state or county.

- Adaptable and Visitable Housing: Affordable and Sustainable
- Changes
  Lisa M. Johnson and Qian Chen
  pp. 588-597 (10 pages)
  http://dx.doi.org/10.1061/41020(339)60
  Abstract | PDF (479 KB) | Permissions

Sustainable development has attracted considerable interest from residential communities to 'green' existing homes and build new sustainable ones. The focus is on the reduction of energy consumption and environmental impacts of the built houses. This paper takes the issue of human/societal factors, especially the visitability, into consideration in developing sustainable houses. Visitability refers to a specially designed house that allows people with disabilities to visit and live in. This paper emphasizes the importance of visitable housing and discusses probably the biggest barrier—potential cost increases in construction. A list of visitable and accessible housing features is given to help homeowners and building practitioners select the most appropriate features for their specific projects with no or minimal cost increases. This paper delivers an important message to the general public and building professionals that making specific changes initially can not only reduce the cost of housing renovations for people with disabilities but also allow the homes to be sustainable considering long term human dynamics. It also calls for the support from legislators and home developers for this movement.

LEED Certification: A Constructor's Perspective
John Schaufelberger and Joshua Cloud

pp. 598-607 (10 pages) http://dx.doi.org/10.1061/41020(339)61

Abstract | PDF (416 KB) | Permissions

The Leadership in Energy and Environmental Design (LEED) green building rating system has been gaining increased attention. Considerable literature has been published that describes the roles of the owner and designer, but little research has been published on the role of the constructor. To identify issues relative to the constructor's role, a study was undertaken to assess past experiences of builders that have undertaken LEED-certified projects. Contractors who built 22 projects in ten states were

surveyed to determine their experiences. From the survey results, the trends, best practices, and lessons learned were compiled and evaluated. The study results indicated that integrated project delivery methods were more conducive to the delivery of LEED-certified projects than was a design-bid-build approach. Through analysis of the data collected, a four-step guide was developed that can be used by constructors who are considering working on LEED-certified projects.

Optimization Model for the Selection of Materials Using the LEED

Green Building Rating System

Daniel Castro-Lacouture, Jorge A. Sefair, Laura Flórez, and Andrés

L. Medaglia

pp. 608-617 (10 pages)

http://dx.doi.org/10.1061/41020(339)62

Abstract | PDF (486 KB) | Permissions

The green building philosophy has recently taken a central role in the construction industry, mitigating the environmental impact of buildings. Buildings are responsible of a large portion of harmful emissions and use a large fraction of the total natural resources. Moreover, the bad quality of indoor environments in office buildings can affect the health of employees, reducing their productivity. Because materials used in construction projects are responsible for a significant fraction of this environmental footprint, a better selection and use of materials could lead to a green certification such as the one given by the Leadership in Energy and Environmental Design (LEED) rating system. This paper illustrates how an optimization model can be used to help decision makers to select the right materials, incorporating design and budget constraints while maximizing the number of materialrelated LEED-based credits. A case study based on real data is analyzed from different angles to demonstrate the effect on the optimal choice of materials due to changes in construction market conditions.

Quantification of Carbon Footprint on Underground Utility Projects
Shaik Sihabuddin and Samuel T. Ariaratnam
pp. 618-627 (10 pages)

http://dx.doi.org/10.1061/41020(339)63 Abstract | PDF (420 KB) | Permissions

The utilization of traditional open-cut methods for the installation of underground utilities has been common practice in the construction industry for many years. Today, engineers are being tasked with the requirement of selecting a suitable construction method that not only offers the most economical solution, but also minimizes impact to the environment. Trenchless construction methods offer such solutions for installing new utilities and rehabilitating existing infrastructure. The use of multiple construction equipment during open-cut construction, along with extended project schedule, invariably results in considerably more emitted emissions into the atmosphere compared to employing trenchless methods, which have minimal on-site equipment

requirements. Pollutants such as carbon dioxide (CO<sub>2</sub>), carbon monoxide (CO), nitrogen oxide (NO<sub>X</sub>), particulars matter (PM), and sulfur oxide (SO<sub>X</sub>) are identified by the United States Environmental Protection Agency (US EPA) as emissions emitted from equipment engines. This paper describes a methodology developed for quantifying the carbon footprint of a typical underground utility project. Case studies of trenchless pipe replacement, horizontal directional drilling, trenchers, and traditional open-cut are used to demonstrate the reduction in emissions by adopting trenchless technologies. Reducing emissions into the atmosphere is a vital step in developing sustainable solutions for infrastructure construction.

Improving Energy Efficiency in Building through Automated

Computer Design Process
Jason Charalambides
pp. 628-635 (8 pages)
http://dx.doi.org/10.1061/41020(339)64
Abstract | PDF (584 KB) | Permissions

Passive solar heating and light control have been traditionally accomplished through simple rules that matured to shape vernacular architecture. Although many more issues were addressed, the comfort level in terms of thermal energy as well as light control, were key issues in traditional buildings. New materials and techniques altered the balances, setting the use of new types of energy as essential parts of modern design. The power of modern technology, though applied toward the use of materials to generate viable enclosures, it has not been used to its full potential toward the efficient use of solar energy and against the dependency of commercially available energy. The use of computers aiding us toward design has been limited in practice to electronic drafting or modeling [Aish, 2000]. Other than the recently developed packages like Ecotect that integrates to commercially available Computer

- Aided Design (CAD) software, relatively minimal was the work done toward aiding a designer to energy consumption in a visually responsive interface. In order to facilitate the designer in an efficient manner, an algorithm that seamlessly works within commercially available CAD/BIM packages has been developed. The developed program has the advantage of generating an initial input by itself into the CAD interface instead of retroactively evaluating a pre-existing form that the designer has already generated. It determines the optimum openings and shading devices for a given space at any specific latitude and interactively generates virtual models for the user. The main issues addressed are thermal comfort and light control. Although it is not anticipated that passive solar control will provide thermal comfort under all possible scenarios, the algorithm offers optimum use of solar energy.
- Key Processes in the Building Delivery of Green Hospitals
  Elena Enache-Pommer and Michael Horman
  pp. 636-645 (10 pages) | Cited 1 time
  http://dx.doi.org/10.1061/41020(339)65
  Abstract | PDF (573 KB) | Permissions

The healthcare industry is one of the largest and most significant built environment markets today with over 120,000 buildings in the United States. Moreover, in the next 15 years, an estimated \$300 billion will be spent on hospital construction across the United States. Therefore, there is a great opportunity for research and improvements to be made in this area. The built environment has a great impact on healthcare, particularly on the health, safety and well-being of patients and staff. Green healthcare can enable

improved clinical outcomes; lower operating costs, energy consumption and water use. Healthcare facilities are amongst the most complex types of facilities to design, construct and operate. This research study outlines the findings from four children's hospitals with different levels of sustainability in regards to, the project delivery process, greening strategies and lean principles. The key processes investigated are: transparency in relation to green outcomes, owner commitment, early team selection, team experience, early adoption of green, the commissioning process, energy modeling and the role of the construction management team

in the delivery of a green hospital. The findings provide a detailed description and analysis of the delivery process for each case study. The results show that certain delivery process attributes vary with the level of sustainability being sought by the hospitals, with the top three attributes being: owner commitment, expertise on sustainable delivery and early timing of sustainable objectives.

An Investigation of Real Option Theory to Evaluate Design,
Procurement, and Construction of Renewable Energy Facilities
Carol Menassa and Feniosky Peña Mora
pp. 646-654 (9 pages)
http://dx.doi.org/10.1061/41020(339)66
Abstract | PDF (1021 KB) | Permissions

Now a day, the architecture, engineering and construction (AEC) community has to find effective tools and methods through multidisciplinary research to deal with pressing issues of sustainability. One important aspect of sustainability is the underlying costs associated with the design, procurement, construction, and operation and maintenance of renewable energy facilities both in the United States and abroad. This paper investigates theories from financial engineering, particularly real option theory, and methods of incorporating them with life cycle costing to perform economic analysis studies of constructing and operating renewable energy facilities with specific emphasis on biofuel production. It is perceived that the results of this research will allow the decision maker to dynamically account for the uncertainties in the project cash flows through the application of real options when performing financial evaluations leading to life cycle cost analysis of biofuel production facilities. The last section of the paper illustrates the added value obtained from applying one of the several real option scenarios related to the timing of the investment.

Economic and Environmental Analysis of Residential Greywater

Systems for Toilet Use
Scott Glick, Angela Acree Guggemos, and Santosh Prakash
pp. 655-664 (10 pages)
http://dx.doi.org/10.1061/41020(339)67
Abstract | PDF (564 KB) | Permissions

The use of greywater for residential toilet flushing could decrease freshwater demand considerably if adopted nationally. Before this is done, a full understanding of the estimated environmental and economic impacts for greywater systems is needed. New and retrofit residential systems were studied using life-cycle assessment (LCA) and life-cycle cost (LCC). Health considerations were not evaluated as part of this study. The LCA results indicate that both systems have a net environmental benefit over their lifetimes. Based upon current potable water costs, the net present value of the LCC indicates that both systems have net costs. As water rates increase to reflect scarcity, these net costs should decrease or become net savings. Using grey water systems for toilet flushing is environmentally feasible for individual homes whether new or retrofitted. Implementing these systems on a larger scale would

reduce the demands on potable water supplies and on sewage treatment facilities and may improve their economic feasibility.

- Sustainability for Advanced Technology Facilities
- Allan D. Chasey and Atul Kumar Jain
  pp. 665-674 (10 pages)
  http://dx.doi.org/10.1061/41020(339)68
  Abstract | PDF (1553 KB) | Permissions

The concept of "Green" building has been heightened in significance due to concerns regarding the world's climate. This "Green" concept is increasingly accepted throughout the world and its impact is being felt in different sectors of the construction industry. Leadership in Energy and Environmental Design (LEED), developed by the U.S. Green Building Council, is a standard to rate different facility types relative to optimizing energy and environmental performance. Semiconductor manufacturing facilities, commonly referred to as `Fabs', are special construction projects. LEED for New Construction (LEED NC) has been used to assess performance of resource intensive facilities, but

assess performance of resource intensive facilities, but modifications and improvements to the current LEED rating system are needed to help better define and construct high performing resource intensive facilities. This paper outlines a foundation for defining the parameters to help develop resource efficient facilities. This includes understanding the resource requirements of the semiconductors manufacturing facilities and how they differ from other facilities in terms of water and energy requirements. It identifies potential areas that need to be addressed when developing criteria to rate resource intensive facilities.

- Financial Model for Insuring against Catastrophic Storm Risks
- E Islam H. El-adaway pp. 675-684 (10 pages) http://dx.doi.org/10.1061/41020(339)69 Abstract | PDF (459 KB) | Permissions

Risks and uncertainties represent an integral part of the construction process that negatively affects executed projects, contracting parties, and the industry as a whole. In fact, natural hazardous events become extremely important at construction developments that allow low or zero tolerance levels. Concerns regarding catastrophic losses have limited the commercialization of certain projects and activities. This paper proposes a financial model for insuring against catastrophic storm risks that affect construction - projects through a cost-benefit analysis. The challenge with

modeling such severe conditions is that they are so rare that it might take thousands of years of experimental data to ensure that all possible events have been properly measured and captured. Under this study, the historic data in relation to storm events in Mississippi between 5/31/2006 and 5/31/2008 was analyzed using Chandler *et al.* (2001) technique to estimate loss parameters. This dataset was then bootstrapped using Iman and Conover technique to impose correlation and generate simulated dataset of 5,000 points. Finally, the bootstrapped data was modeled using a Monte Carlo simulation

that is based on option theory to calculate the fair-valued premium for an interrelated insurance policy. This insurance product would: (1) fund any destructive effect in connection with construction projects; (2) allow comparing catastrophic risks against benefits by putting a dollar value to such risks; and (3) solve the non linearity problem between wind speed and associated losses. It is the author's hope that the developed model could be extended to form a nationwide insurance policy against catastrophic storm risk. Furthermore, the same principles exploited under the model beforehand could be slightly modified in order to be applied on other extreme weather events such as hurricanes and tornadoes.

Development of the STAR Tool for the Management of

Shutdown/Turnaround/Outage Projects
Donald A. Whittington and G. Edward Gibson, Jr.
pp. 685-694 (10 pages)
http://dx.doi.org/10.1061/41020(339)70
Abstract | PDF (457 KB) | Permissions

Renovation and revamp projects are ubiquitous in the construction industry. Shutdowns/turnarounds/outages (STO) are a subset of renovation and revamp projects in the industrial sector. These events typically occur when planned disruptions to normal use or operation of a manufacturing facility take place to facilitate maintenance, enhancements, or tie-ins. It is common to have several construction projects executed during an STO and the integration of the activities is often problematic. Little research has been performed studying the integration of these multiple projects, work-scopes and maintenance activities into a single STO. Based on a Construction Industry Institute research study, this paper will provide a discussion of STOs, including unique challenges, describe a new tool/management approach developed to aid industry professionals in planning and coordinating the multiple projects within an STO, and provide guidance to practitioners.

Integrating Productivity and Safety Analysis with the Task Demand
Methodology: A Case of Concrete Paving

Panagiotis `Takis' Mitropoulos and Manoj Namboodiri pp. 695-704 (10 pages)
<a href="http://dx.doi.org/10.1061/41020(339)71">http://dx.doi.org/10.1061/41020(339)71</a>
Abstract | PDF (454 KB) | Permissions

This paper presents a new methodology to measure at the same time the safety risk and productivity of an operation and assess how changes in operation parameters affect both productivity and safety. The methodology is based on a cognitive approach to safety and considers two key factors for assessing the likelihood of accidents:

= (1) the exposure to a hazard, and (2) the `task demand' during the exposure, which reflects the difficulty to do the work safely with respect to a particular hazard. The task demand indicates the probability that there will be an error during the exposure to the hazard that can lead to an accident. The paper describes the methodology, and presents a case study that analyzes the likelihood of accident and the productivity of a paving operation. The case

illustrates how this methodology can be used to evaluate the effect of production variables on both productivity and safety. The conclusion discusses the strengths and limitations of the approach.

The Validity of Data Dependent System Modelling to Predict
Relative Physiological Workload during Construction Work
Tariq Abdelhamid, Lili Xi, and John G. Everett
pp. 705-615
http://dx.doi.org/10.1061/41020(339)72

http://dx.doi.org/10.1061/41020(339)72 Abstract | PDF (459 KB) | Permissions

The measurement of oxygen uptake during physical work activities is considered a good measure of the physiological workload experienced by construction workers. Many work physiologists advocate reporting the measured oxygen uptake as a percentage of maximum oxygen uptake, a ratio commonly known as relative workload. The main advantage of this ratio is the subject-specific workload it provides. This enables the tailoring of work demands to the ability of individual workers. Determining relative workload is arithmetically simple once maximum oxygen uptake is known. However, finding exact maximum oxygen uptake requires intricate and complicated laboratory procedures that may be dangerous for unfit individuals. Therefore, despite sacrificing accuracy, maximum oxygen uptake prediction techniques offer an attractive alternative. This paper presents a large scale validation of a maximum oxygen uptake prediction method that uses in-situ collected sub-maximal oxygen uptake data. The methodology, developed using twenty subjects and verified on eight construction workers, was based on the use of time series analysis techniques and the hypothesis that oxygen uptake data are serially dependent. The validation results using 100 subjects arrived at a  $\pm 0.65$  liter  $\,$  min<sup>-1</sup> standard error of prediction for  $VO_{2\text{max}}$ . The findings indicate that the assumptions of the original model hold but with less prediction accuracy. Improvement of the prediction accuracy will require the utilization of a multiple regression model that can incorporate more subjectspecific results.

Catastrophe Risk Management for Private-Public Partnership (PPP)

Infrastructure Projects
Qiyu Qian and Robert Tiong Lee Kong
pp. 716-725 (10 pages)
http://dx.doi.org/10.1061/41020(339)73
Abstract | PDF (477 KB) | Permissions

Globally, there is an increasing trend in adopting a Public-Private partnership (PPP) scheme to develop infrastructure systems. At the same time, the frequency and severity of losses from catastrophes have increased dramatically. In order to keep the infrastructure - projects sustainable, catastrophe risk management as one necessary

- projects sustainable, catastrophe risk management as one necessary component of risk management must be taken into consideration. Combined with the special properties of PPP projects, a pro forma cash flow model would form a useful basis for quantifying catastrophic risks and measuring the dynamic financial gap of the project. A catastrophe risk management strategy will be developed based on an in-depth understanding of the project's risk exposure, a good understanding of the timing in the needs for resources and project's internal financial capacity to retain the risk, cost tradeoffs between different types of risk financing instruments and mitigation efforts, and last but not least, layered risk-transfer portfolio setup.

Applying Insurance Pricing Theory for Pricing ADR as an

Insurance Product

Xinyi Song, Carol Menassa, Feniosky Peña-Mora, and Robert F. Conger

pp. 726-735 (10 pages)

http://dx.doi.org/10.1061/41020(339)74

Abstract | PDF (434 KB) | Permissions

As litigation is recognized as a costly and time-consuming method to resolve disputes, alternative dispute resolution (ADR) techniques are being adopted in construction projects to help handle disputes in a more effective way. However, there are potential costs related to ADR implementation as it requires expenditures to cover the expenses incurred by the owner's/contractor's employees and third party neutrals. Normally those costs are determined during the project planning phase prior to the actual occurrence of disputes. In this paper, the possibility of pricing ADR as an insurance product will be explored. It is similar to the concept of "premium" in insurance industry, although it may be structured more like a self-- insurance program. The objective is to provide project participants with an economic advantage by investing a certain amount of premium in the beginning of the project in exchange for compensation from the insurance company in the uncertain event of an unknown ADR cost that may be incurred during the construction phase. Insurance pricing theory's underwriting concepts will be utilized to develop similar concepts in ADR pricing. A conceptual model will be presented to perform the ratemaking process by drawing an analogy from health insurance. An example of a construction project is used to illustrate the mathematical calculations required to determine the premium of the proposed ADR techniques.

A Prediction Model for Construction Project Time Contingency

Dalia Mohamed, Florida Srour, Wael Tabra, and Tarek Zayed pp. 736-745 (10 pages)
<a href="http://dx.doi.org/10.1061/41020(339)75">http://dx.doi.org/10.1061/41020(339)75</a>
Abstract | PDF (1182 KB) | Permissions

Construction projects often suffer from high level of uncertainty in many fronts: time, cost, quality, safety, etc. Most of the conducted research focuses on estimating cost contingency. Even though construction project scheduling has received extensive attention of researchers, time contingency was not treated well in the literature. In order to meet the deadline of a project, an accurate scheduling should be sought. Due to the nature of construction projects, scheduling should be flexible enough to accommodate changes without negatively affecting the overall duration of the project. As such, the objectives of the research presented in this paper are to

assess the factors that affect scheduling contingency and to develop a simple model that can be used in estimating the expected time contingency of a construction project. A survey was conducted on sixteen construction companies in Montréal, Québec, Canada. The data obtained from the survey was then processed using Analytic Hierarchy Processes (AHP) to develop a time contingency model. Results show that the predicted time contingency matches with 87% the estimated contingency for real projects. The developed time contingency model showed robust results.

Project Risk Identification Methods for Construction Planning and

Execution

Robert G. Batson

pp. 746-755 (10 pages)

http://dx.doi.org/10.1061/41020(339)76

Abstract | PDF (424 KB) | Permissions

Risk identification is the often neglected first step in the risk management process: potential problems specific to the project must be identified before quantification of the magnitude of the risk, or consideration of prevention or mitigation actions. This paper presents two research conclusions: systematic project risk identification during the transition from the design to construction (planning) phase benefits from a taxonomy of risk areas/potential problems for the specific type of construction involved; during construction execution, earned value analysis is an effective method to identify emerging risks from readily available project data bases. A taxonomy was developed from published references for infrastructure construction projects, validated by construction managers, and is the main contribution of this paper. Fifteen "risk areas" were used to organize 96 potential problems.

Supporting Market Entry Decisions for Global Expansion Using

Real Option + Scenario Planning Analysis

Du Yon Kim, Byungil Kim, and Seung Heon Han

pp. 756-765 (10 pages)

http://dx.doi.org/10.1061/41020(339)77

Abstract | PDF (469 KB) | Permissions

The world has witnessed the dramatic expansion of international construction markets during the last decades, particularly around the developing economies and energy resource-rich countries. However, despite the booming markets, the risks of emerging regions have also increased under the rapidly changing environments confronting global contractors. Most of all, success in overseas business mainly depends on selecting a right market to enter. Accordingly, the right market selection requires global firms to carefully carry out the scientific market entry decision by evaluating country risks, market prospects, firm's capability, level of competition, and among others. This study aims at developing a market entry model by the use of real option analysis (ROA) and scenario planning, which places emphasize on firm's strategic flexibility against uncertainties encompassing the overseas construction markets. Based on the suggested approach, global

contractors are expected to make a better decision rather than a widely used static NPV approach in pursuing, postponing, or abandoning a prospective market to their capacity with a consideration of uncertainties as well as its flexible option value.

Resilience Engineering: A New Approach for Safety Management
D. Schafer, T. S. Abdelhamid, P. Mitropoulos, and T. Mrozowski

pp. 766-775 (10 pages) http://dx.doi.org/10.1061/41020(339)78 Abstract | PDF (491 KB) | Permissions

This exploratory paper proposes a resilient engineering approach to construction safety that departs from traditional views. Accidents are commonly viewed as a linear combination of causes and risks are viewed as arising from unreliable system components such as operators and technology. Traditional risk assessment views model system safety mainly in terms of linear structures that are by nature reactive and based on hindsight. Additionally, current safety models tend to ignore the demands imposed upon projects such as

production pressures and tempo changes in work flow. To remedy the shortfalls of construction safety mentioned above resilience engineering is presented as a new and proactive outlook on construction safety management. In this paper the genesis of the resilience engineering concept is examined and resilience engineering is posed as an exemplar for construction safety. An existing model that supports resilience engineering principles, the Functional Resonance Accident Model (FRAM), is examined in a construction scenario.

Identifying and Communicating Project Stakeholder Risks

Peter J. Edwards, Paul A. Bowen, Cliff Hardcastle, and Peter J. Stewart
pp. 776-785 (10 pages)

http://dx.doi.org/10.1061/41020(339)79 Abstract | PDF (1206 KB) | Permissions

A systematic approach to risk management is needed if stakeholders are to effectively manage the risks they face on projects. Risk identification is a critical part of risk management. Using observations from project experience and class workshops, the effectiveness of several risk identification techniques is explored in the context of construction projects. Emphasis is given to the risk communication processes involved, from an intrastakeholder perspective. While some techniques are effective for

particular project stages and situations, a work breakdown structure (WBS) approach is found to be a good `fall back' method for identifying project risks at the schematic and subsequent design stages. The more detailed the WBS, the more comprehensive the risk identification can be. Multiple risk identification workshops are recommended during the pre-construction phase of a project. Precise risk statements are essential for effective risk communication, and project risk schedules should be developed as active documents.

- A Risk-Based Approach to Contingency Estimation in Highway
  - Project Development
    Keith R. Molenaar and Craig R. Wilson
    pp. 786-795 (10 pages)
    http://dx.doi.org/10.1061/41020(339)80
    Abstract | PDF (410 KB) | Permissions

Highway design and construction projects require engineers and construction managers to coordinate a multitude of human, organizational, technical, and natural resources. These projects can be extremely complex and fraught with uncertainty. The engineering and construction complexities are often overshadowed by economic, societal, and political challenges. The outcome of these challenges has too often been significant cost escalation. This paper discusses a three-tier approach for risk analysis and

- contingency estimation that has been developed through two National Cooperative Highway Research Projects (NCHRP) and applied in one research project for the Minnesota Department of Transportation (Mn/DOT). The three tiers have been defined as: Type I risk identification and contingency percentage; Type II qualitative risk analysis and identified contingency items; and Type III quantitative risk analysis and active contingency management. This paper explains this approach and discusses its application in the highway project development process.
- Aligning Pre-Construction Planning and Project Management in the Electrical Construction Industry

  Ziad Bou Nasr and Cindy L. Menches

  pp. 796-805 (10 pages)

  http://dx.doi.org/10.1061/41020(339)81

http://dx.doi.org/10.1061/41020(339)81 Abstract | PDF (491 KB) | Permissions

Efficient management of construction projects continues to be an important topic. A recently completed study evaluated the relationship between pre-construction planning and project performance in the electrical construction industry. The research resulted in a model Electrical Pre-Construction Planning Process that was based on projects that were well-planned and performed well. A follow-on study was recently launched to develop a model Electrical Project Management Process that is aligned with the model Pre-Construction Planning Process. The study is investigating the theory that properly aligned planning and

execution and will result in more successful project outcomes. Five exploratory interviews were conducted with project managers to help the researchers conceptualize the electrical project management process, and this data was used to develop a questionnaire that was sent to 2000 electrical construction companies about their project management practices. The results of the survey were used to revise the electrical project management process, and an initial alignment was performed to identify connections and disconnects between planning and project management. The results of the alignment process revealed that, currently, safety and labor control receive insufficient attention

during planning, and, likewise, budget preparation and sequencing receive insufficient attention during project management. Hence, comprehensive interviews are scheduled to investigate the impact of these disconnects on performance and to revise the planning and management processes to provide better alignment and facilitate more successful project performance.

Multi-Objective Optimization of Resource Scheduling in

Construction Projects

Dho Heon Jun and Khaled El-Rayes

pp. 806-815 (10 pages)

http://dx.doi.org/10.1061/41020(339)82

Abstract | PDF (1457 KB) | Permissions

Resource allocation and leveling techniques have been widely used to consider the impact of resource availability and minimize undesirable resource fluctuations. These techniques and existing models deal with two distinct problems in a sequential manner rather than simultaneously. This paper presents the development of a robust multi-objective optimization model for optimizing resource allocation and leveling simultaneously. Two innovative resource leveling metrics, namely Release and Re-Hire (RRH) and Resource Idle Days (RID), are incorporated in the model to directly measure and minimize the negative impact of resource fluctuations on construction productivity and cost. An application example is analyzed to illustrate the use of the model and demonstrate its capabilities in generating optimal tradeoffs between resource utilization efficiency and project duration.

Automated CPM Schedule Generation for Early Project Planning:

Methodology and Case Study
Youngsoo Jung, Young Hwan Lee, Sungkwon Woo, Jin-Soo Yang,
Sang-Mok An, Young-Seok Oh, and Bok Nam Lee
pp. 816-825 (10 pages)
http://dx.doi.org/10.1061/41020(339)83
Abstract | PDF (1510 KB) | Permissions

The purpose of this paper is to propose a methodology to automatically generate CPM schedules for preliminary project planning. This paper mainly focuses on a process of generating CPM activities using automatically calculated durations. Historical labor productivity is utilized as a governing parameter to convey the previous experiences into a new project. Several different adjustment mechanisms are applied in order to enhance the

reliability and to reduce the workload. A real-world case of implementing the proposed methodology is introduced in order to evaluate the effectiveness and viability of the method. Managerial issues including strategic significance from a corporate perspective, cost effectiveness for this ad hoc system, and overhead efforts to maintain standardized and structured historical databases are discussed as well.

Developing Effective Visual Representations to Monitor Project
 Performance

Namhun Lee and Eddy M. Rojas pp. 826-835 (10 pages) http://dx.doi.org/10.1061/41020(339)84 Abstract | PDF (777 KB) | Permissions

During construction, project managers constantly review actual project performance and resolve any discrepancies between asplanned and as-built progress. However, it is not always easy to perform these activities since numerous individuals and parties are involved in a typical project. This is where visual representations may be helpful. Several charts and diagrams have been traditionally used in construction to visually track performance. This paper

analyzes the advantages and disadvantages of traditional visual representations such as bar charts, network diagrams, line of balance charts, and S-curve graphs, and introduces a set of design principles for the development of non-traditional visual representations to effectively monitor project performance. The paper closes with examples of new visualization schemes built according to those principles.

Life-Cycle Assessment of Titanium Dioxide Coatings

Marwa Hassan

pp. 836-845 (10 pages) http://dx.doi.org/10.1061/41020(339)85 Abstract | PDF (563 KB) | Permissions

The use of Titanium Dioxide (TiO<sub>2</sub>) ultrafine particulates as coating for concrete pavement have received considerable attention in recent years as these coatings can trap and absorb organic and inorganic air pollutants by a photocatalytic process. Despite these promising benefits, the promotion of TiO<sub>2</sub> coatings based on a single factor such as air quality does not provide a complete evaluation of this technology and may omit critical environmental factors that should be considered in sustainable material selection decision-making process. The objective of the research reported in this paper was to determine the life-cycle assessment of TiO<sub>2</sub> coating technology. To achieve this objective, a life-cycle inventory (LCI) that quantifies the energy, abiotic raw material inputs, and emission of TiO<sub>2</sub> coatings from cradle to grave was developed.

Based on this inventory, life-cycle impact assessment of TiO<sub>2</sub> coatings for concrete pavement was determined using the BEES impact assessment model. Results showed that the use of titanium dioxide coating reduces the environmental impact of four main categories: acidification, eutrophication, criteria air pollutants, and smog formation. However, during production phases and due to the consumption of fossil energy, titanium dioxide will cause an increase in global warming, fossil fuel depletion, water intake, ozone depletion, and impacts on human health. Based on the overall environmental performance of this product, life cycle assessment shows that titanium dioxide coating has an overall negative score of –0.70 indicating that the addition of this surface layer will have an overall positive effect on the environment.

- Global Optimization of Dynamic Site Layout Planning in
- Construction Projects
  Khaled El-Rayes and Hisham Said
  pp. 846-855 (10 pages)
  http://dx.doi.org/10.1061/41020(339)86
  Abstract | PDF (731 KB) | Permissions

Dynamic site layout planning in construction projects focuses on identifying the location and space of temporary construction facilities on sites while considering the dynamic changes in the needs and availability of site space over the project duration. Existing dynamic site layout planning models generate layout plans of construction stages chronologically without considering their future effects which may lead to non-optimal or infeasible solutions. This paper presents the development of an Approximate

- Dynamic Programming (ADP) model that is capable of globally optimizing dynamic site layout plans of construction projects in order to minimize overall site layout costs. The developed model is equipped with the look-ahead capabilities of ADP to consider the future effects of site layout decisions in early stages on layout quality and feasibility in future stages. An application example is analyzed to illustrate the use and capabilities of the developed model in generating global optimal solution for dynamic site layout planning of construction projects.
- Understanding Collaborative Working Processes of Temporary
- Project Teams in Large-Scale Construction Projects

  JeongWook Son and Eddy M. Rojas

  pp. 856-865 (10 pages)

  http://dx.doi.org/10.1061/41020(339)87

  Abstract | PDF (599 KB) | Permissions

Current construction planning and control practices have proven to be less than ideal when applied to large-scale projects. This derives, in part, from the lack of explicit methods to model organizational

- and information-handling issues of temporary project teams. An emerging approach called social network analysis (SNA) is introduced in this paper as a way to overcome this limitation.
- Modeling the Effect of an Alternative Review Process: Case Study
- of a State Permitting Agency
  Peter P. Feng, Iris D. Tommelein, and Glenn Ballard
  pp. 866-875 (10 pages)
  http://dx.doi.org/10.1061/41020(339)88
  Abstract | PDF (850 KB) | Permissions

The purpose of the research presented here is to describe workflow through an organization that reviews submissions for building permit approval and understand the effect of an alternative review

process on the time to permit assuming a certain level of staffing conducting the review. The alternative review process engages the state review agency early in reviewing the design with the owner, architect, engineer, and contractor. Data was obtained from a state permitting agency to develop a simulation model of an alternative

review process and the disruption rework causes on the permitting approval process. This simulation model shows that incorporating an alternative review process can shorten the overall time to permit a hospital. It also shows that the alternative review process shifted the design and permitting curve, reducing the time to permit, while increasing the workload up-front. This research recognizes that the alternative review process does not suit all projects, and that permitting agencies who adopt it must judiciously decide how to staff their organization to support process implementation.

An Approach to Classifying Uncertainties in Construction
 Schedules

H. Clay Phillips, Susan M. Bogus, and Timothy J. Ross pp. 876-885 (10 pages) http://dx.doi.org/10.1061/41020(339)89 Abstract | PDF (452 KB) | Permissions

Planning is arguably the most difficult, and important, phase of the construction process. One must have a very intimate grasp of what tasks are needed to complete a job, how they might be interdependent and therefore sequenced, and the construction methods, equipment, and skill sets required to execute them. At this step there is already a tremendous amount of uncertainty injected into the schedule, which only increases when site conditions and human interaction are added. The result is the existence of uncertainty in several forms in construction schedules, including probability, possibility, belief/plausibility, and fuzzy. There are different methods for uncertainty quantification based on the type of uncertainty. When applied appropriately, these methods can lead to an overall level of uncertainty (or total uncertainty) in a schedule. The first step to quantifying the total uncertainty in a schedule is to define and classify the types of uncertainties that may occur. Through a series of thought experiments a flow chart has been developed and examples provided to illustrate a classification process.

Assessment of Methods for Adjusting Construction Cost Estimates
by Geographical Location
Giovanni C. Migliaccio, Paul Zandbergen, and Adam A. Martinez
pp. 886-895 (10 pages)
http://dx.doi.org/10.1061/41020(339)90
Abstract | PDF (654 KB) | Permissions

Conceptual cost estimates are fundamental to the success of construction projects. These early estimates are commonly prepared through the aid of historical data and later adjusted to take into account specific project characteristics such as location. The common practice for adjusting estimates for location is to use sets of location cost factors. When a location is not represented in the chosen data set, the nearest location factor is usually selected. The validity of this interpolation method has not been substantiated. Geographical Information System (GIS) techniques are used to conduct spatial analysis of the RSMeans' City Cost Index (CCI) national reference data. Spatial auto-correlation of these CCI values

is tested to determine the validity of the nearest neighbor interpolation method at both the national and state level. In addition, an alternative analysis between nearest neighbor and the state average CCI value methods has been performed. Findings reveal positive, nationwide correlation between proximity and CCI values. In addition, 19 individual states showed highly significant results of positive correlation between proximity and CCI value and no state showed significant negative correlation. The alternative analysis between nearest neighbor and state average was not conclusive. Half the time the nearest neighbor measure provided a better estimate, and half the time the state average proved a better measure.

Time Prediction for Highway Pavement Projects Using Regression

Analysis

Ahmed M. Abdel Aziz pp. 896-905 (10 pages)

http://dx.doi.org/10.1061/41020(339)91

Abstract | PDF (959 KB) | Permissions

In the planning stages of highway projects sufficient information may not be available to apply a full scale critical path method (CPM) analysis to predict the duration and the use of approximate methods would be required. Highway agencies usually record representative information about the projects, e.g. planned and actual duration, quantities of work, project cost, and project miles. By applying a set of statistical methods to these historical records, a prediction of the duration of a project could be obtained. This paper describes the development of time prediction models through the application of general multiple regression analysis, ridge regression analysis, and nonlinear partial least-square regression analysis to project data from Washington State Department of Transportation. The models were developed using representative variables including the hot mix asphalt (HMA) quantity, grading quantities, and surfacing quantity, the number of project miles, and the contract value. Cluster analysis was used to further improve the prediction ability of the models. Through an example, the developed models were validated against an actual project data. The prediction of project duration is an important objective of highway agencies and the developed models would be helpful tools to achieve this objective.

Development of People-Based Maps Experience Management

System for Construction Projects

Yu-Cheng Lin

pp. 906-915 (10 pages)

http://dx.doi.org/10.1061/41020(339)92

Abstract | PDF (1951 KB) | Permissions

Experience management refers to the processes governing the creation, storage, reuse, maintenance, dissemination and evaluation of experience relevant to a particular situation or problem-solving context. In the construction industry, experience can be reused and shared among the involved engineers and experts to enhance

construction processes and minimize costs and problem solving time. This study proposes a novel and practical People-Based Maps (PBM) approach to capture and represent engineer experience and project knowledge This approach enables users to survey and access the experience of previous engineers and experts in similar projects and to appropriately assess their tacit and explicit experience. This study applies Experience Management principles to the construction phase of construction projects and develops a Construction Assistant People-based Map Experience Management (APMEM) system for contractors. The APMEM system is then applied in a Taiwan high-tech science park construction project to verify the proposed methodology and demonstrate the effectiveness of sharing previous experience in the construction phase. Experience can be captured and reused to benefit future projects by effectively utilizing people-based maps and web technology during the construction phase of a project. The combined results of this study indicate that an APMEM system can provide an effective experience management platform for other construction projects by adopting a people-based maps approach.

Application of the Resource-Constrained Critical Path Method to

Multiple Calendars and Progressed Schedules

Jesús M. de la Garza and Kyunghwan Kim

pp. 916-925 (10 pages)

http://dx.doi.org/10.1061/41020(339)93

Abstract | PDF (789 KB) | Permissions

This paper presents an application case study of the Resource-constrained Critical Path Method (RCPM). RCPM is a heuristic algorithm to identify resource-dependent activity relationships (resource links) during resource-constrained scheduling. Through resource links, the schedule provides reliable activity floats and the critical path, which traditional resource-constrained scheduling techniques hardly provide. A prototype RCPM system is developed based on the algorithm. The RCPM system is integrated with

- Primavera Project Planner (P3), so it imports the project data directly from a P3 project, performs required RCPM procedures, and updates the P3 project to establish an RCPM schedule. The system is also equipped with functions to handle PDM logic relationships, multiple calendars, and progressed schedules. This paper briefly reviews the key elements of the RCPM procedures and demonstrates how it can be applied to a P3 schedule that consists of multiple calendars and a progress stage. The presence of Phantom Float in P6 is also illustrated.
- Validating Renovation Phasing Schedules Using 4D Model Based
- Methods
  Peggy Ho and Martin Fischer
  pp. 926-935 (10 pages)
  http://dx.doi.org/10.1061/41020(339)94
  Abstract | PDF (599 KB) | Permissions
  - Scheduling major renovation work in an occupied building represents a major challenge to project managers. Multiple

stakeholder requirements from the owner, building occupants, and renovation crews must all be satisfied within a tightly constrained physical environment. This paper describes a renovation planning framework and prototype system that enables project managers to explicitly define and automatically check renovation requirements. The framework is based on and extends 4D model based methods. A case study is presented to show how the framework was used to analyze and compare renovation phasing schedules on a building renovation project. The results indicate that the framework enables better identification of scheduling issues and alternatives.

Mapping Actors and Roles in Construction Knowledge

J. Zhang and T. E. El-Diraby
pp. 936-945 (10 pages)
http://dx.doi.org/10.1061/41020(339)95
Abstract | PDF (621 KB) | Permissions

Modelling actors and roles and mapping their relations have great significance in the construction industry for effective communication. However, the attention and effort in this area is far lagged behind the research of construction product modelling and process modeling. After discussing the philosophical root of understanding actors and roles, this paper proposed an ontological model for major entities involved in construction, and then established criteria of identifying actors and roles. Based on the two taxonomies (for actors and roles) developed in this study, an innovative way of mapping an actor to its possible roles was illustrated.

The Current Use of Offsite Construction Techniques in the United States Construction Industry

Even though the use of offsite construction techniques provides

<u>Na Lu</u> pp. 946-955 (10 pages) http://dx.doi.org/10.1061/41020(339)96 Abstract | PDF (438 KB) | Permissions

numerous significant advantages the current level of using these techniques in the US construction industry is limited. This study aimed to 1) identify the driving forces and challenges in using these techniques in residential, commercial, and industrial sectors, 2) investigate the perceived benefits and barriers, and 3) compare the perceived benefits and barriers in using these techniques in residential, commercial, and industrial construction sectors. The - results indicated that benefits of using these techniques include 1) reducing the project schedule, 2) reducing the need for skilled craft workers, 3) reducing the negative environmental impact, and 4) increasing safety performance. The most significant barriers were 1) transportation restraints and 2) inability to make changes onsite. The top 3 driving forces for its use were 1) to reduce the construction duration, 2) to reduce the overall project schedule, and 3) to compensate for the effect of incremental weather conditions. The top 3 challenges were 1) the inability to make changes onsite, 2) transportation constraints, and 3) limited design options. Several

practical recommendations were proposed in this study based on the findings.

Forecasting Construction Manpower Demand: An Econometric

<u>Model</u>

<u>James M. W. Wong</u>, <u>S. Thomas Ng</u>, <u>Albert P. C. Chan</u>, and <u>Y. H. Chiang</u>

pp. 955-968 (14 pages)

http://dx.doi.org/10.1061/41020(339)97

Abstract | PDF (503 KB) | Permissions

Manpower forecast has become an important management tool for decision makers and policy makers to match and structure the skills of the workforce. National planners are also increasingly aware that the competitiveness and growth of the nation, as well as its social welfare, depend in no small degree on the full exploitation of the skills of its people. However, there is very limited research in establishing a comprehensive manpower demand forecasting model in construction. This paper aims to present the framework of an advanced econometric model for estimating the manpower demand - in construction. Vector error correction modeling, regression analysis and exponential smoothing technique were applied to develop the relationships between manpower demand and the relevant variables in the construction industry. The forecasting models developed can benefit the construction industry by providing critical information on the future construction manpower requirements and assist policy makers and training planners to formulate training strategies. Apart from this practical use, the research also contributes new knowledge and a solid framework to the area of manpower forecasting and planning.

The Core of Eden: A Case Study on Model-Based Collaboration for

Integrated Project Delivery

Kihong Ku

pp. 969-978 (10 pages)

http://dx.doi.org/10.1061/41020(339)98

Abstract | PDF (1590 KB) | Permissions

The paper examines the model-based design processes in the Eden Core project in Cornwall, U.K., concentrating on key aspects of the collaboration between the architect, consultants, design-build general contractor, and fabricator, within the specific context of an innovative biomimetic design which integrates sustainability and a biologically inspired complex geometric roof structure. It is analyzed how 3D models support building simulation processes and how various computer modeling techniques are used to resolve the complex geometric issues of the timber grid-shell roof fabrication design. The paper aims to contribute to the understanding of model-based practices in the design of sustainable and complex-shaped buildings, and adds to the growing body of descriptive literature on integrated practice. The study provides (1) a 3D modeling process map which describes how modeling supports collaboration and how it integrates into traditional design processes, and concludes with

- (2) alternative approaches to overcome the challenges of model-based collaboration approaches.
- Visualization Configuration Model for Integrating Presentation of
- Construction Project Management Data
  Jianguo David Ye and Thomas Froese
  pp. 979-988 (10 pages)
  http://dx.doi.org/10.1061/41020(339)99
  Abstract | PDF (657 KB) | Permissions

Construction management tasks involve and produce voluminous, multidimensional data. Although many tasks currently are supported with software tools, it still requires great mental effort for project personnel to read information in datasets and analyze relationships from one dataset to another. Information visualization is widely considered to hold the potential of providing insights from datasets by visually presenting project management data and information relationships. Many visualization solutions are available to the construction domain, but they usually focus on specific application tasks, lacking flexibility and data integration in - user-interaction for construction management. This paper proposes a Visualization Configuration Model (VCM), a novel visualization technique for construction project management. Integrated with the Industry Foundation Classes (IFC) data model, the VCM is developed to be a configurable visualization environment, facilitating user-interactions to explore voluminous information. The model framework and underlying theories for integrating model components are provided. Through analysis of two case

Stakeholder Views on IT in Construction: A North American

scenarios, the paper demonstrates the capability of the VCM supporting view configuration and illustrates the potential of visualization to benefit construction management tasks.

Perspective

Kasun N. Hewage, Janaka Y. Ruwanpura, and George F. Jergeas pp. 989-998 (10 pages)

http://dx.doi.org/10.1061/41020(339)100

Abstract | PDF (421 KB) | Permissions

Recent research study at the University of Calgary, Canada emphasized the immediate need of effective communication among all the construction project stakeholders — i.e. workers, construction managers, consultants, and clients. All these stakeholders identified lack of `on-site' communication as a key reason for low productivity. Construction industry is known for its' resistance in using Information Technologies (IT) compared to

manufacturing, military, and agriculture industries. However, the construction workers participated in this study expressed their willingness and ability to use modern communication technologies in the work environment. The construction companies (managers) were not confident to acquire information technologies to the construction workface. They pointed the unavailability of information on worker abilities, technologies, possible outcomes, related costs, and benefits as the reasons for this resistance.

Technology developers had difficulties to understand specific communication needs of the construction industry. This paper presents a summary of the views and concerns expressed by the construction industry stakeholders in North America regarding the possibilities and opportunities in using IT in construction projects. The paper is concluded with a set of recommendation to optimize the IT use in the construction industry.

Rules and Guidelines for Improving the Mechanical, Electrical, and Plumbing Coordination Process for Buildings

Thomas M. Korman
pp. 999-1008 (10 pages)
http://dx.doi.org/10.1061/41020(339)101
Abstract | PDF (424 KB) | Permissions

The coordination of mechanical, electrical, and plumbing (MEP) systems has become a major challenge for complex buildings and industrial plants. The coordination process involves locating equipment and routing connecting elements for each system to avoid physical interferences. For the past several years the MEP coordination has involved sequentially comparing and overlaying drawings from multiple trades, in which representatives from each MEP trade work together to detect, and eliminate spatial and

\_ functional interferences between MEP systems. This multidiscipline effort is time-consuming and expensive. With the recent development of Building Information Modeling (BIM) this process is now able to evolve with the software technology; however, the software technology available today is limited to performing geometric clash detection. Based on observational research, this paper recommends a process for performing MEP coordination and describes how rules and guidelines can improve the MEP coordination process in buildings using BIM software.

Assessing the Environmental Impacts of Lean Supply System: A
Case Study of Rebar Supply in High-Rise Condominium
Construction Projects
Jin-Woo Bae and Yong-Woo Kim
pp. 1009-1018 (10 pages)
http://dx.doi.org/10.1061/41020(339)102
Abstract | PDF (476 KB) | Permissions

Lean production is a systemic approach to meeting customer expectations by reducing waste. Many believe that implementing lean leads to achieving "green." The authors explore the validity of this statement. They investigate the environmental impacts of prefabrication with just-in-time (JIT) delivery on reinforced bar using a building construction case study. The results suggest that prefabrication with JIT delivery consumes less energy but emits more CO<sub>2</sub>. The study also finds that delivery batch size per truck as well as delivery distance are important factors.

Production Flow in the Construction of Tall Buildings
Rafael Sacks and Rebecca Partouche
pp. 1019-1028 (10 pages)

## http://dx.doi.org/10.1061/41020(339)103 Abstract | PDF (925 KB) | Permissions

The time required for construction of tall buildings, whether measured per floor or per unit area built, increased consistently through most of the 20<sup>th</sup> century despite the introduction of improved construction technologies that increased productivity. The explanation for this seeming contradiction appears to lie in the ways in which resources are applied. As buildings have themselves become more technologically complex, so have the networks of subcontracting that characterize their supply chains become more extensive. Construction management has become focused on contract management and the allocation of risk and less on explicit management of the production system. Thus project participants, consciously or unconsciously, each allow buffers of time, work in process and materials to accumulate. A parametric discrete event simulation model has been compiled that enables experimentation with various aspects of the construction process of tall commercial/office buildings. The impacts of the production strategy relating to accumulation of work in progress (WIP) were explored. The simulation results explain how accumulation of WIP contributes to increasingly longer construction durations for tall buildings. That understanding can be leveraged to propose changes in the way the construction of tall buildings can be organized to achieve shorter and less costly projects.

How to Lower the River to Reveal the Rocks without Putting a

Hole in Your Boat
Glenn Ballard
pp. 1029-1037 (9 pages)
http://dx.doi.org/10.1061/41020(339)104
Abstract | PDF (1621 KB) | Permissions

Toyota's example has inspired revolutionary changes in the way all manner of goods and services are designed and produced. One of the key features of this new approach is the self-imposition of necessity. Rather than wait for customers or competitors to compel innovation and improvement, In the famous words of Toyota Chief Engineer Ohno, we should 'lower the river to reveal the rocks'; i.e., deliberately reduce the buffers of time, capacity, inventory and financial contingency that are currently necessary to absorb variation and uncertainty, in order to reveal where the production system needs to be changed. This paper explores the application of Ohno's advice in the construction industry. Examples of successful implementation are provided, and methods are proposed to reduce the risk of putting a hole in your commercial boat.

Overcoming the Hurdle of First Cost: Action Research in Target

Costing
Glenn Ballard and Zofia K. Rybkowski
pp. 1038-1047 (10 pages)
http://dx.doi.org/10.1061/41020(339)105
Abstract | PDF (796 KB) | Permissions

Advocates of sustainable and evidence-based design initiatives argue that building owners can secure favorable internal rates of return when full life cycle building costs are considered. While the argument has merit, these decision-makers express concern about overcoming the hurdle of first cost. To reduce first cost, a number of lean construction practitioners are exploring a planning and design process called target costing. Target costing in construction is a collaborative cost management process that relies on business plan validation to determine what is to be delivered and what the client is willing and able to pay for a project—before establishing the allowable cost. When warranted, a target cost may be set even lower than the allowable cost in order to spur innovation. Once a target cost has been established, the project is collaboratively designed to that target cost. This case study examines the target costing techniques used during the design of an 850,000 square foot (approximately 79,000 square meters) medical center. Qualitative and quantitative outcomes are explored, as well as implications for future projects.

Structural Design Iteration: The Application of DSM to Seismic
 Retrofit

<u>Stan J. Tuholski</u> and <u>Iris D. Tommelein</u> pp. 1048-1057 (10 pages) http://dx.doi.org/10.1061/41020(339)106 Abstract | PDF (1371 KB) | Permissions

Iteration in design or re-design is commonplace within architectural, engineering, and construction (AEC) projects. Positive iteration is often required to optimize design solutions around competing objectives. This runs counter to the misconception shared by many engineers that iteration is negative and linearity in design is preferable and achievable through adequate pre-planning. We have identified a void in the practical application and theoretical development of design theory within the structural engineering community, particularly in methodologies that address iteration in design. This void points at a lack of understanding that contributes to project performance deficiencies as characterized by cost over-runs and sub-optimal design, among

others. This paper presents a seismic retrofit case study for the purpose of developing a greater understanding of the role of iteration in design. The design structure matrix (DSM) work planning tool is used to optimize the sequence of design activities in order to limit the required impacts of necessary iteration allowing for efficient information flows. The implementation of DSM on this project had two valuable effects: (1) the optimized matrix correctly identified the dependency network underlying the primary design problem as evident by the alignment of observed iterative activities and the derived block, and (2) the DSM provided a common framework for discussing iterative tasks and planning collaborative design efforts within the multi-disciplinary team.

- From Lean to Green Construction: A Natural Extension
- Isabelina Nahmens

pp. 1058-1067 (10 pages) http://dx.doi.org/10.1061/41020(339)107 Abstract | PDF (700 KB) | Permissions

One of the focuses of Lean construction is waste elimination from the construction processes, while creating a culture within the company of continuous improvement. Similarly the focus of Green construction is on the removal of waste from the construction process and in addition it adds an environmental dimension to lean construction. Lean and green construction share a common goal, to eliminate as much waste as possible. Therefore, not producing waste is both the most efficient and cost effective approach to sustainability. Current industry practice shows that lean construction is already the dominant paradigm in factory built home manufacturing, yet its impact on the environment is less understood. This paper uses a case study approach which - demonstrates that a natural byproduct of applying lean techniques is the reduction of waste which overlaps with one of the key objective of green building. This case study presents the application of lean production in the wall/partition department of a HUD-code home plant which resulted in a 10% reduction of raw material-reducing wallboard damaged during the construction stage. This paper compares material wastes before and after a Kaizen event performed in the wall/partition department. Lessons learned from this case study are discussed and used to proposed guidelines to

integrate lean methodology and green building. Findings from this

Progress Monitoring of Construction Projects Using Neural
Networks Pattern Recognition
Ashraf Elazouni and Osama Abdel-Wahhab
pp. 1068-1078 (11 pages)
http://dx.doi.org/10.1061/41020(339)108
Abstract | PDF (475 KB) | Permissions

research will contribute to a better understanding of the applicability of lean strategies in the housing industry and its

impact on the environment.

The traditional monitoring practice involves collecting actual quantity data, and comparing against a benchmark which represents the relevant planned data. The encountered well-known problem in monitoring is that the quality of the collected data is often subjected to great variation due to the variation in the reporting skills as well as the willingness to record data accurately. A potential technique to circumvent this problem is to conduct the comparison against multiple possible outcomes rather than a single-valued benchmark.

The main objective of this research is to utilize the Pattern Recognition (PR) techniques to classify the work planned at specified cut-off dates during the planning stage and use the classification to monitor and evaluate the progress during the construction stage. The PR technique generalizes a virtual benchmark to represent the whole project based on multiple possible outcomes generated at a given cut-off date. The generalization feature offers a potential tool to overcome the problem of variation in the quality of data collected. Patterns are

constructed to encode work of the project at different cut-off dates. Finally, the PR concept and technique proved its robustness to monitor and evaluate progress of construction projects based on the technique of Critical Path Method (CPM).

Material Selection in Building Construction Using Optimal Scoring

Method (OSM)

<u>Jorge A. Sefair, Daniel Castro-Lacouture</u>, and <u>Andres L. Medaglia</u> pp. 1079-1086 (8 pages)

http://dx.doi.org/10.1061/41020(339)109

Abstract | PDF (561 KB) | Permissions

Trying to choose the best-performance materials is a complex task due to the vast set of alternatives. Likewise, multiple criteria such as environmental impact, design suitability, and cost are often considered by the purchasing agent when evaluating materials. Moreover, it is often the case that these criteria present tradeoffs making the decision's complexity even higher. Thus, considering that buildings have multiple systems with their own material selection process, this paper proposes the application of a systematic and efficient method to support this process. The proposed method ranks candidate materials using multiple criteria, allowing decision makers to easily include their preferences. A computational experiment based on data available in the literature

Development of Project Level Engineering Productivity

is presented to demonstrate its use in the construction field.

Benchmarking Index

<u>Pin-Chao Liao</u>, <u>Stephen R. Thomas</u>, <u>William J. O'Brien</u>, <u>Stephen P. Mulva</u>, and Jiukun Dai

pp. 1087-1095 (9 pages)

http://dx.doi.org/10.1061/41020(339)110

Abstract | PDF (460 KB) | Permissions

Since 2002, the Construction Industry Institute (CII) has been working to develop a standardized Engineering Productivity Metric System (EPMS) for benchmarking purpose. In this system, engineering productivity is defined as a ratio of direct engineering work hours to the engineering outputs as measured by Issued for Construction (IFC) quantities. The EPMS consists of six major engineering disciplines with a number of underlying metrics. Engineering productivity can be accordingly benchmarked at any of these levels; however, there is a lack of project-level engineering

productivity. The challenge is that IFC quantities are measured with different units and thus are difficult to roll up to the project level. To overcome this barrier, this study examines three approaches for aggregating engineering productivity metrics to the project level based on 112 heavy industrial projects. The selected project level engineering productivity measurement best summarizes the underlying engineering productivity metrics and provides a macro view of engineering performance. It allows owners and engineering organizations to benchmark engineering productivity at the project level. It also lays the foundation for future engineering productivity analysis and research.

A Framework for Integrating Elitist GA and Project Management
 Tool

<u>Jin-Lee Kim</u> and <u>Ralph D. Ellis, Jr.</u> pp. 1096-1104 (9 pages) http://dx.doi.org/10.1061/41020(339)111 <u>Abstract | PDF (1074 KB) | Permissions</u>

A construction schedule generated by most commercial project management software packages does not guarantee its optimality when the resources are limited. Project scheduling software revealed the limitation because they employ the simple priority rules for generating a precedence and resource feasible schedule, even though they provide the schedules in a reasonable amount of time regardless of the size of project. This paper proposes a framework for integrating Elitist Genetic Algorithm (EGA) and a project management tool for construction resource-constrained project scheduling as an add-in function. The integration framework aims to help project planners to compare the scheduling results generated from the existing project management software packages such as Primavera Project Planner and MS Project with those obtained from EGA. A case example based on a commercial warehouse project is introduced to show the possibility of implementing the function through the integration of data structure.

Creating Value in Housing Projects: The Use of Post-Occupancy
Analysis to Develop New Projects
Thaís da C. L. Alves, George S. Costa, and José de P. Barros Neto
pp. 1105-1114 (10 pages)
http://dx.doi.org/10.1061/41020(339)112
Abstract | PDF (452 KB) | Permissions

Value generation is a goal of the Lean Production/Construction philosophy. However, defining value is difficult as value may vary according to user requirements and the capacity to afford desirable products and services. This paper presents two post-occupancy studies carried out in Brazilian housing projects and discusses how the results were collected, analyzed, and how they can be used for developing new projects. The first study presents the method used to collect and analyze data regarding users' opinions about housing units in low-income housing projects funded by the Brazilian Government. The second study presents the method used to capture the opinion of users of high-rise housing projects for medium- and high-income families. Results were categorized to reflect client satisfaction vs. how much they value specific items (importance) and provided designers and developers with clues about what clients actually value and how close/far the developers are from meeting or exceeding client expectations.

Preparation of Incongruous Economic Datasets for Regression
Analysis
Gunnar Lucko and Zane W. Mitchell, Jr.
pp. 1115-1124 (10 pages)
http://dx.doi.org/10.1061/41020(339)113

## Abstract | PDF (433 KB) | Permissions

Datasets in construction engineering and management are not always as clean and consistent as one would desire. They may not match in format or content between companies that are studied and within them they may require substantial preparation. This makes the examination of theories and the extrapolation of trends from historic data more difficult than it is for carefully controlled experimental studies or collection of new data. The purpose of this

paper is not to review the regression models that the writers developed during their research, but to focus on the data preparation that had to be applied prior to those analyses. It outlines general techniques that can be applied to field data from construction companies or data repositories to give researchers various best practices that will help gleaning further truths from already existing data.

Risk Assessment for Water Mains Using Fuzzy Approach

## H. Fares and T. Zayed
pp. 1125-1134 (10 pages)
http://dx.doi.org/10.1061/41020(339)114
Abstract | PDF (1614 KB) | Permissions

The concept of responding to the risk of water pipelines failure has been undergoing through a great change from being active to being proactive to failure events by planning for rehabilitation plans that maintain the water main in good working conditions. This paper designs a framework to evaluate the risk of water main failure using hierarchal fuzzy expert system. There are sixteen risk-of-failure factors that represent both the probability of failure and the negative consequences of failure event and are categorized into four main

risk-of-failure factors. A risk of failure model is built that evaluates the risk of pipelines failure using Fuzzy Expert System technique that accounts for the uncertainty usually encountered when evaluating the risk of failure. Some of the findings are that the pipe age gives a strong indication of the condition of the water mains, then, the pipe material and breakage rate come into play, and that the damage to surroundings/business disruption has the most negative impact of a failure event.

An Automated System for Optimizing Temporary Housing

Arrangements after Natural Disasters
Omar El-Anwar, Khaled El-Rayes, and Amr Elnashai
pp. 1135-1144 (10 pages)
http://dx.doi.org/10.1061/41020(339)115
Abstract | PDF (626 KB) | Permissions

Post-disaster temporary housing programs have often been criticized due their inability to fulfill the socioeconomic and safety needs of the displaced families and for being overly expensive.

- Impact assessment software systems, such as HAZUS-MH (FEMA) and MAEviz (Mid-America Earthquake Center), enable emergency planners to estimate post-disaster housing damage and displacement of families. This paper presents the development of an

automated temporary housing planning system, which incorporates a preparedness model and a response model. These models are currently being integrated in MAEviz to support decision-makers in (1) identifying available temporary housing resources prior to a disaster; and (2) identifying optimal configurations of post-disaster temporary housing arrangements, which satisfy the safety and socioeconomic needs of displaced families, while minimizing public expenditures. A large-scale application example is provided to demonstrate the capabilities of the system in identifying feasible temporary housing alternatives and generating optimal trade-offs among different optimization objectives.

- Planning Post-Disaster Reconstruction Efforts of Damaged
- Transportation Networks
  Wallied Orabi, Khaled El-Rayes, Ahmed Senouci, and Hassan AlDerham
  pp. 1145-1153 (9 pages)
  http://dx.doi.org/10.1061/41020(339)116
  Abstract | PDF (1039 KB) | Permissions

Planning the reconstruction efforts of damaged transportation networks in the aftermath of natural disasters is a challenging task due to the limited availability of construction resources. The utilization of these limited resources can have a significant impact on the societal needs of minimizing the reconstruction costs and the performance loss of the damaged transportation network. These resources therefore need to be deployed and utilized in an effective and efficient manner that accomplishes these two critical objectives. This paper presents the development of a planning

- model for post-disaster reconstruction efforts for damaged transportation networks. The model is developed in four stages: (1) allocating the available reconstruction resources to competing recovery projects; (2) estimating the reconstruction costs; (3) measuring the performance loss during the recovery period; and (4) optimizing the reconstruction efforts to minimize reconstruction costs and performance loss. An application example is analyzed to illustrate the use of the model and demonstrate its capabilities in planning post-disaster reconstruction efforts.
- Assessment of Impacts of High-Rise Buildings on the Electric and Transportation Infrastructures in Developing Countries

  María L. Peralta, Dulcy M. Abraham, and Fred L. Mannering pp. 1154-1163 (10 pages)

  <a href="http://dx.doi.org/10.1061/41020(339)117">http://dx.doi.org/10.1061/41020(339)117</a>
  Abstract | PDF (541 KB) | Permissions

A tendency affecting the performance of infrastructures in developing countries is the growing number of high-rise buildings. These new buildings put intense pressure on existing infrastructures especially on road transportation and electric systems, due to the traffic they generate and the high number of resources they require to function. This study uses a hybrid approach to assess the impact of high-rise buildings on two critical infrastructures. First, a user-equilibrium approach is used to assess the effect of high-rise

buildings on the performance of the transportation infrastructure. A system dynamics model is then used to evaluate the effect of high-rise buildings on the electric power system. The models developed are verified and validated using data from a large city in a developing country. This research illustrates the impact of new disruptors, on the services provided by critical infrastructures and on their interdependencies in developing countries.

Extracting Surveying Goals from Point Clouds to Support

Construction and Infrastructure Inspection
Pingbo Tang and Burcu Akinci
pp. 1164-1173 (10 pages)
http://dx.doi.org/10.1061/41020(339)118
Abstract | PDF (1209 KB) | Permissions

Inspectors need accurate and efficient methods for obtaining geometric information about facilities for construction and infrastructure management. Laser scanners can capture millions of 3D points, which have mm accuracy, in minutes, and hence can streamline extraction of geometric information. Currently, extraction of geometric information is done manually. This paper describes a case study, which shows that manual approach is inefficient and error-prone. Aiming at improving the efficiency and effectiveness of extracting survey goals, this paper discusses computer interpretable representations of surveying goals as a first step towards extraction of surveying goals. The described approach targets enabling surveyors to compose surveying goals as \( \facility \) parts, features, operations \( \) tuples. Reasoning mechanisms can transform user-defined surveying goals described by these tuples into a sequence of measurement operations to generate results.

Infrastructure Risk Management in Renewable Energy Projects

Using Risk Flexibility Theory
Nicola Chiara
pp. 1174-1183 (10 pages)
http://dx.doi.org/10.1061/41020(339)119
Abstract | PDF (496 KB) | Permissions

Climate-change-concerns coupled with US high dependence on exhaustible resources such as oil and coal have urged the federal government to support a more extensive private sector participation in developing renewable energy projects. Though the federal government has pledged to promote private participation in renewable energy developments through supportive legislation and ad-hoc incentives, the private investors' profitability in such

e projects is not yet secured. As a result, potential private investors are reluctant to invest in renewal energy projects making it a lose-lose situation. Literature survey shows that there are currently no effective methods to address this important issue. This paper presents a novel approach, namely the Risk Flexibility Theory, to correctly assess the financial feasibility of renewable energy projects. Risk Flexibility Theory properly reckons flexibilities that can make the project more profitable by offsetting part of the project risk.

The Impacts of Infrastructure PPPs on Public Sector Capacity

Stephan F. Jooste and Raymond E. Levitt
pp. 1184-1193 (10 pages)
http://dx.doi.org/10.1061/41020(339)120
Abstract | PDF (401 KB) | Permissions

Infrastructure PPPs have been shown to overcome public sector capital and capacity constraints in the short term, and therefore, increase the viability of desired infrastructure projects. Their longterm impacts on the capacities of governments have, however, not been considered as explicitly. This issue is especially salient in the context of infrastructure delivery due to the central role that the public sector continues to play in the process of selecting, delivering and managing infrastructure assets. This paper seeks to illuminate this issue through a review of literature on "public sector capacity," the changing role of government, public sector contracting, and outsourcing in the private sector. We draw on these diverse streams of literature to (i) clarify the concept of "public sector capacity", (ii) identify two broad typologies of capacity, and (iii) investigate the possible impacts of PPPs on each of these dimensions of capacity. We conclude with suggestions for future research.

Automated Defect Detection in Urban Wastewater Pipes Using

Invariant Features Found in Video Images
W. Guo, L. Soibelman, and J. H. Garrett, Jr.
pp. 1194-1203 (10 pages)
http://dx.doi.org/10.1061/41020(339)121
Abstract | PDF (3386 KB) | Permissions

This paper presents an innovative approach for condition assessment and defect reporting in wastewater infrastructure, enabling automatic detection of defects and patterns from inspection imagery in realistic settings. In this paper, we describe an automated three-step approach using local scale-orientation-illumination invariant features to detect surface defects and critical patterns from inspection imagery of wastewater pipelines. The invariant features were extracted by applying Scale Invariant Feature Transform (SIFT) algorithm developed by Lowe. The devised detection approach has been experimentally tested using a diverse collection of digital images acquired from real inspection scenarios. The evaluation results demonstrated that it is possible and feasible to use such an automated approach for defect reporting and condition assessment in wastewater pipe infrastructure.

Real-Time Concrete Damage Visual Assessment for First

Responders
Zhenhua Zhu, Ioannis Brilakis, and Gustavo Parra-Montesinos
pp. 1204-1213 (10 pages) | Cited 1 time
http://dx.doi.org/10.1061/41020(339)122
Abstract | PDF (1476 KB) | Permissions

First responders are in danger when they perform tasks in damaged buildings after earthquakes. Structural collapse due to the failure of critical load bearing structural members (e.g. columns) during a post-earthquake event such as an aftershock can make first responders victims, considering they are unable to assess the impact of the damage inflicted in load bearing members. The writers here propose a method that can provide first responders with a crude but quick estimate of the damage inflicted in load bearing members. Under the proposed method, critical structural members (reinforced concrete columns in this study) are identified from digital visual data and the damage superimposed on these structural members is detected with the help of Visual Pattern Recognition techniques. The correlation of the two (e.g. the position, orientation and size of a crack on the surface of a column) is used to query a case-based reasoning knowledge base, which contains apriori classified states of columns according to the damage inflicted on them. When query results indicate the column's damage state is severe, the method assumes that a structural collapse is likely and first responders are warned to evacuate.

Interactive Augmented Reality Visualization for Improved Damage

Prevention and Maintenance of Underground Infrastructure

Amir H. Behzadan and Vineet R. Kamat

pp. 1214-1222 (9 pages)

http://dx.doi.org/10.1061/41020(339)123

Abstract | PDF (1093 KB) | Permissions

During a typical excavation operation, there is a high risk of inadvertently damaging the existing subsurface utilities. Such incidents cause significant financial loss to the project and can delay or abruptly halt ongoing construction. In many cases, they also pose a life threat and often result in accidental deaths. As a result, constructors are required to protect utility systems during excavation operations. In this paper, the applicability of advanced visualization and tracking technologies to improve work safety

during urban construction projects by enhancing the visual perception of construction equipment operators is discussed. The integration of Augmented Reality (AR) visualization and the Global Positioning System (GPS) is explored to create real time views of an excavation site in which CAD models of the underground utilities can be accurately superimposed over live video streams of the real world with the resulting views being displayed to the equipment operator in real time.

Collaborative Tunneling Simulation Using Synthetic Environments

S. M. AbouRizk, S. Hague, M. Al-Bataineh, and S. Fernando

pp. 1223-1232 (10 pages)

http://dx.doi.org/10.1061/41020(339)124

Abstract | PDF (1208 KB) | Permissions

Project managers can use simulation tools during the preconstruction planning phase to coordinate human and material resources and weigh alternative scenarios proposed for a specific project, define activities, create schedules, predict completion dates, and calculate costs. Tunneling is a good test case for simulation due to its repetitive and sequential activities. Unfortunately, current simulation techniques are only effective when the models can be limited in scope and are limited to single users, as original construction simulation frameworks were meant to tackle processes and operations rather than integrate projects within collaborative, multi-user environments. Furthermore, current simulation environments fail when the interactions involve different models. This paper discusses a proposed system for the development of a multi-user decision support framework to improve the planning phase of construction. The framework is designed to house a collaborative environment in construction and will be informed by the Construction Synthetic Environment (CoSyE) method based on High Level Architecture (HLA).

Development of a Numerical Model for Predicting Pulling Loadson Fusible PVC Pipe

Samuel T. Ariaratnam, Arnab Ghosh, Richard (Bo) Botteicher, and Siggi Finnsson

pp. 1233-1242 (10 pages)

http://dx.doi.org/10.1061/41020(339)125

Abstract | PDF (577 KB) | Permissions

Design engineers are continually evaluating alternative pipe and construction options for addressing their municipal infrastructure needs. Today, the use of trenchless technologies such as Horizontal Directional Drilling (HDD) in the municipal sector has increased significantly as an alternative construction method. The nature of the HDD process necessitates the use of continuously joined pipe products capable of being pulled in, as opposed to pushed in by segmental installations. Fusible PVC<sup>TM</sup> (FPVC<sup>TM</sup>) pipe is one such material for installation of water and wastewater, pressure and nonpressure infrastructure using HDD. While maximum safe pull load criteria have been developed for this material, the present pull load predictive tools for the HDD process are highly variable and, in some cases, overly conservative in evaluating safe pull loads. This paper describes the results of research to develop a predictive model for HDD installations specific to FPVC<sup>TM</sup>. A three step process was used to define the methodology of predicting safe pull load. The first step was the development of empirical equations based on existing methodologies, experience, and PVC-specific material properties. The second step involved field measurement of pipe pull loads during HDD installations. Finally, the field data was compared to the calculated data and the predictive equations were modified accordingly. This design model, calibrated by field verified data, enables a more accurate determination of required safe pull load for any given HDD installation.

Horizontal Directional Drilling on the Snoqualmie River: A Case Study

<u>Kimberlie Staheli</u> and <u>Michelle Ramos</u> pp. 1243-1249 (7 pages) http://dx.doi.org/10.1061/41020(339)126

## Abstract | PDF (2801 KB) | Permissions

The Kimball Creek project was a 1,000-foot long crossing of the Snoqualmie River near Snoqualmie, Washington. The 16-inch diameter DR-9 HDPE pipe was installed by Horizontal Directional Drilling (HDD). Staheli Trenchless Consultants (STC) provided submittal review and full time consultation during construction. As part of the submittal review, STC independently checked the

contractor's estimated pullback forces for the pipe length, diameter, and type. During construction, actual pullback forces were recorded and were later compared to both STC's and the contractor's predicted pullback forces. This paper discusses the construction for this project and compares actual pullback forces to the contractor's and engineer's predictions.

- Risk Allocation in Standard Forms of General Conditions for
- Tunneling Contracts
  Veerasak Likhitruangsilp and Photios G. Ioannou
  pp. 1250-1259 (10 pages)
  http://dx.doi.org/10.1061/41020(339)127
  Abstract | PDF (751 KB) | Permissions

A construction contract is the primary tool for allocating risk among the contracting parties in the project, especially the owner and the contractor. Presently, many tunneling contracts are prepared by adopting or modifying standard forms of general conditions, which were not designed primarily for tunneling work, leading to contractual disputes among the parties. This paper examines risk allocation in standard forms of general conditions as applied to tunneling projects. Tunneling risk factors were first identified based on literature, analyses, and interviews with experienced tunnel

- engineers. We then investigated the general conditions of actual tunneling contracts, including the standard forms of general conditions prepared by the International Federation of Consulting Engineers (FIDIC) in order to analyze and compare their risk allocation schemes. The results show that some tunneling risk factors are not included, whereas some are not clearly or appropriately allocated in such contracts. The paper finally discusses some important considerations on improving the risk allocation in the standard forms of tunneling contracts based on the International Tunneling Association (ITA) recommendations.
- Trenchless in Anchorage Case Studies

  Michelle Ramos and Brian Gastrock

  pp. 1260-1269 (10 pages)

  http://dx.doi.org/10.1061/41020(339)128

  Abstract | PDF (1815 KB) | Permissions

This paper presents case studies involving trenchless construction in Anchorage, Alaska. Like many cities around the nation,

Anchorage is growing beyond the capacity of their infrastructure. Much of the infrastructure for downtown Anchorage was installed in the early 1900's and is in need of repair or replacement. Because the city has grown and developed around the infrastructure, it is

difficult to repair or replace the utilities using conventional opencut construction. The following case histories highlight different trenchless technologies and how the technologies are being applied within Anchorage. The trenchless technologies include horizontal directional drilling (HDD), sliplining, Cured-in-Place Pipe (CIPP) and guided boring (also known as pilot tube microtunneling).

Integrated Simulation-Based Scheduling for Module AssemblyYard

<u>H. Taghaddos, S. AbouRizk, Y. Mohamed, and R. Hermann</u> pp. 1270-1279 (10 pages) http://dx.doi.org/10.1061/41020(339)129 Abstract | PDF (1477 KB) | Permissions

Producing a schedule for industrial construction that optimizes resource utilization and meets the delivery dates of competing projects is a complicated task. The scheduler must consider several constraints and uncertainties including limited space, crew skill, and shipment processes in the module yard. This paper presents an integrated simulation-based scheduling framework that pulls the data from a database interface, runs the simulation model, and provides different graphical reports to the user. Although this model has been implemented successfully in the industry, some challenges are not yet solved. A distributed simulation system using High Level Architecture (HLA) is proposed to break down the simulation into a number of components to enhance the performance of the system. This system also helps to reuse these components in future projects and to facilitate the expansion of the model, enabling more complicated process simulations.

Integrating Agent-Based Simulation with Game Theory to
Investigate the Hold-Up Problem in Project Networks
H. I. Unsal and J. E. Taylor
pp. 1280-1289 (10 pages)
http://dx.doi.org/10.1061/41020(339)130
Abstract | PDF (1096 KB) | Permissions

Subcontractor selection strategies employed by contractors can significantly impact short-term project and long-term organizational success. Existing research on subcontractor selection strategy focuses mainly on the evaluation of subcontractors. We extend this perspective by integrating an agent-based simulation model with game theory to examine whether partner selection strategies that do not consider subcontractor selection as a repeated game may lead to - a version of the hold-up problem. The hold-up problem we investigate centers around relationship-specific investments in learning following the introduction of an innovation or organizational change across a project network. We find that a minimum total cost strategy may decelerate the rate of adaptation to an innovation or organizational change. The findings contribute to subcontractor selection strategy literature by simulating the impact of the hold-up problem in project networks, distinguishing task interdependence as a moderating variable, and identifying that the

minimum total cost strategy is a suboptimal strategy for project networks adapting to systemic changes.

Modeling Architecture for Hybrid System Dynamics and Discrete

**Event Simulation** 

A. Alvanchi, S. Lee, and S. M. AbouRizk pp. 1290-1299 (10 pages) http://dx.doi.org/10.1061/41020(339)131 Abstract | PDF (443 KB) | Permissions

Construction systems and projects comprise complex combinations of subsystems, processes, operations, and activities. Discrete Event Simulation (DES) has been used extensively for modeling construction systems, addressing system complexity, and analyzing system behavior. However, while DES is a powerful tool for capturing operations as they occur in reality, DES does have difficulty modeling context and its mutual effects on the operational components of a system. System Dynamics (SD), on the other hand, captures feedback loops that are derived from the context level of a system and that can anticipate system behavior; nevertheless, SD cannot effectively model the operational parts of a system. Hybrid SD and DES modeling provide a set of tools that use the capabilities, while improving upon the disadvantages, of these two approaches. Although initial efforts to develop hybrid SD -DES modeling dates back to the late 1990s, in the construction still no robust architecture for hybrid system developers. This paper

- industry, there are relatively few studies in this area, and there is still no robust architecture for hybrid system developers. This pape addresses these issues by proposing a comprehensive hybrid simulation architecture based on the High Level Architecture (HLA) infrastructure, which can be used by hybrid simulation developers in the construction industry. A typical steel fabrication shop has been modeled based on the proposed architecture, and it has been compared with the ideally developed hybrid simulation architecture.
- Planning Temporary Hoists for Building Construction
- Seokyon Hwang
  pp. 1300-1307 (8 pages)
  http://dx.doi.org/10.1061/41020(339)132
  Abstract | PDF (1014 KB) | Permissions

An effective plan of temporary hoists is important in building construction that demands much vertical transportation of resources during the construction phase. Almost every trade of building project relies on hoists to move personnel, materials, and equipment in vertical direction. Thus, the availability of such equipment inevitably influences performance of each trade. Despite its

significant roles and functions in building construction, it is challenging to develop an effective plan for the procurement, install, and operation of the equipment. One needs to deal with many decision variables and information associated with decision-making with regard to the selection, erection, operation, and maintenance of hoists. Understanding such significance and difficulties, the present research initiative intends to develop a

method that can support decision-making process of planning hoists for building construction. This paper reports the results of the first phase of the present research.

Alliance Team Selection for Infrastructure Projects Using Monte
Carlo Simulations

Mounir El Asmar, Awad S. Hanna, Chul-Ki Chang, and Jeffrey S. Russell

Similar to the design-build delivery system, the alliance delivery

pp. 1308-1317 (10 pages)

http://dx.doi.org/10.1061/41020(339)133

Abstract | PDF (419 KB) | Permissions

system is used here to denote a special form of partnership between the owner and the design-build team, demonstrated through the substantial involvement of the owner. Design-Build/Alliance delivery systems have been implemented successfully for private projects. However, their use in public work has been hindered by many issues including the presence of qualitative selection criteria and the absence of a scientific evaluation process to select the winning team. This paper lays out a framework which facilitates - selecting the best alliance team for a project. Monte Carlo simulations were used to vary all the factors relevant to the decision problem and to uncover biases present in the evaluation. These may arise due to any unfairness of the model represented by the weights of the criteria or any possible discrimination from the evaluators. Use of this tool would complement the high performance of designbuild/alliance project delivery systems and further enhance it by ensuring that the selected team is the best one for the job, thus lowering project risks. A case study dealing with a large utility project illustrates the developed framework.

Real-Time Simulation for Look-Ahead Scheduling of Heavy

<u>Construction Projects</u>

Lingguang Song, Casey Cooper, and Sang-Hoon Lee

pp. 1318-1327 (10 pages)

http://dx.doi.org/10.1061/41020(339)134

Abstract | PDF (534 KB) | Permissions

Heavy construction work is a highly equipment-intensive process, and contractors work under a unique set of conditions that are characterized by various resource constraints and uncertainty. Accurate and timely look-ahead scheduling based on the most recent project data can greatly improve project execution and control. This paper describes a framework of look-ahead scheduling using real-time data collection and simulation techniques. In this

framework, real-time dynamic data of an actual construction operation are collected and used to update a process-simulation model for look-ahead scheduling. Compared with the traditional scheduling methods that are static and time-consuming to maintain and update, the capability of real-time simulation to dynamically incorporate new project data and changes in the work environment offers the promise of improving the accuracy of look-ahead scheduling while reducing modeling burdens on end users. To

demonstrate the feasibility of the proposed framework, a prototype system was developed for asphalt hauling and paving projects.

Development of a Construction Engineering Laboratory Course and

Facility

David W. Johnston

pp. 1328-1337 (10 pages)

http://dx.doi.org/10.1061/41020(339)135

Abstract | PDF (930 KB) | Permissions

As the construction industry has advanced, an array of field quality control, monitoring, and evaluation devices has become available that the construction engineer often must understand and employ to maintain a safe workplace and to meet the quality requirements of the project in real time, not just hope it passes inspection at the end of the project or at intermediate stages. The education of construction engineers needs to provide an understanding of these methods and devices. Most of the methods and devices are invoked as a part of the construction contract specifications, usually citing standard specifications and test methods published by ASTM and other similar organizations. Understanding these standards and their role in the construction process is also important in the educational process. This paper describes the development and implementation of a construction engineering laboratory course and facility to fulfill these needs.

A Balanced View of Sustainability in Civil Engineering and

© Construction

Leidy Klotz and Denise Grant

pp. 1338-1347 (10 pages)

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Abstract | PDF (436 KB) | Permissions

The concept of sustainability is taking a more prominent role in civil engineering and construction curricula all over the world. Sustainability has environmental, economic and social dimensions; however, there is a tendency for the social dimension to receive less focus than the other two. Certainly, with their technical backgrounds and training, the majority of civil engineering and construction students are better prepared to understand and contribute to the environmental and economic dimensions of sustainability. Yet, an understanding of all dimensions is necessary to provide optimal, sustainable solutions to technical problems. The research described in this paper assesses the evolution of students' understanding of sustainability based on the Global Reporting Initiative's Sustainability Reporting Guidelines. Understanding of sustainability is assessed at the beginning and end of a Sustainable Construction course. In addition, students in the course perform one of two types of class projects; a case-study learning project, and a project with a service learning component. Comparing the results between students performing each project type will provide insight into each project type's effectiveness in developing students' understanding of sustainability. This research will reveal the understanding of sustainability inherent in a select group of Civil

Engineering students. The research will also describe the progression of this understanding during a *Sustainable Construction* course and during problem-based and service-learning type projects.

Engagement of Industry in Best Practices Research

G. Edward Gibson, Jr. and Donald A. Whittington pp. 1348-1357 (10 pages)
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Construction industry best practices research requires an interaction and feedback mechanism between industry respondents and academia. Typical research methods such as surveys, source document reviews, and structured interviews are typically used, but suffer from barriers which can hamper results. Examples of these barriers include low response rates, asynchronous communication, time commitment of the researchers and respondents, access to project data, and travel costs. Structured workshops (research "charrettes") are a unique and useful method for facilitating data collection between industry respondents and academic researchers. They combine the best tenets of surveys, interviews and focus groups in an accelerated time frame. This paper will explain how these workshops provide a critical avenue for industry interaction. Characteristics leading to successful charrettes will be outlined. The paper will conclude by describing the benefits of these workshops to researchers including lessons learned from successful workshops.

Assessing Traits for Success in Individual and Team Performance in an Engineering Course

Robert M. Leicht, <u>Angela Lewis</u>, <u>David R. Riley</u>, <u>John I. Messner</u>, and <u>Brent Darnell</u>

pp. 1358-1367 (10 pages)

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Abstract | PDF (789 KB) | Permissions

With increased emphasis on collaboration, integrated project delivery, and high performance project outcomes, the need for improved team and collaborative skills among engineers has created a push for new competencies to be developed within engineering programs. An exploratory study was completed to identify traits of students which are linked to success in a third year undergraduate construction engineering and management course, most notably team projects. The results of the study will be used to - improve professional and collaborative skills in the undergraduate engineering curriculum at Penn State. Ninety-five students in an undergraduate course in the Architectural Engineering Department at Penn State were assessed to identify the individual characteristics which led to success in the course on both an individual and team basis. The students were randomly assigned to teams to complete projects during the spring 2008 semester. Individual exam scores, project scores, and team member evaluations were compared with individual trait assessment, using the Bar-On Emotional Quotient Assessment. The paper provides an introduction to emotional

intelligence (EI), the Bar-On Emotional Quotient Inventory, and why EI is important to the Architectural Engineering and Construction Industry (AEC). The methodology and results of the student assessment are then presented. The results identify individual team member traits which suggest success of collaboration through improved performance in team projects. The paper concludes with future efforts in progress to help students to improve individual and team EI competencies.

- One Approach to Incorporating Sustainable Design into
- Undergraduate Engineering Programs
  J. B. Pocock, Z. Mitchell, and A. J. Bates
  pp. 1368-1377 (10 pages)
  http://dx.doi.org/10.1061/41020(339)139
  Abstract | PDF (1248 KB) | Permissions

Schools with undergraduate engineering programs in many disciplines are working to include environmental sustainability and sustainable design into their curricula. This paper describes an example of how these topics are being built into one construction course and will eventually increase within an undergraduate civil engineering program.

The advancements of digital media and virtual environments have

- Construction Education in Second Life
- Kihong Ku and Yogesh Gaikwat pp. 1378-1387 (10 pages) http://dx.doi.org/10.1061/41020(339)140 Abstract | PDF (5674 KB) | Permissions

begun to greatly impact typical classroom environments. However, traditional construction education approaches of lectures, seminars, and project group work, have not really taken advantage of the potential of these new tools. Research shows that virtual reality simulation technology offers an effective and complementary teaching method to address the competencies and skills of the construction management process. While there are successful examples of virtual reality applications such as the Building Management Simulation Center in the Netherlands, these facilities - limit virtual learning to users who are within the physical boundaries of these buildings. This paper describes the potential benefits of Second Life — a virtual worlds environment — for simulating role-playing in the construction process and outlines the technical challenges to its adoption for construction education. The core elements of a construction planning scenario for an on-campus building at Virginia Tech is discussed, expanding into an applicable safety training scenario that involves features of construction equipment (e.g., tower crane, forklift) and scaffolding. The authors conclude with future research needs of this new learning environment.

- Enhancing Construction Education with Contextual Service
- E Learning
  Christine M. Fiori and Anthony D. Songer

pp. 1388-1397 (10 pages) http://dx.doi.org/10.1061/41020(339)141 Abstract | PDF (387 KB) | Permissions

Recent calls to reform engineering education place emphasis on applied math and science within the broader context of globalization, economics, the environment, and society. To solve these complex problems, interdisciplinary approaches are required and demand additional teamwork skills of new graduates. While this vision for the future is well documented in *The Engineer of* 2020 and the ABET engineering accreditation criteria, many engineering faculty are at a loss for how to cultivate and assess these skills in students, particularly when the problem is viewed as adding new content to already packed degree programs. The Center for Leadership in Construction in the Myers-Lawson School of Construction at Virginia Tech provides an educational program that combines classroom learning with authentic field experiences. The program responds to the demands for integrating technical and social domains in a multi-disciplined, globally sensitive paradigm. The course that illustrates the efforts of the program is "Sustainable Construction in the Global Village". The course focuses upon public health infrastructures in resource poor countries and engages

students to engineer in context by working in highly complex sociotechnical systems that depend on humans for operations and maintenance. Student teams develop iterative design and construction solutions for community identified needs and then build their projects in country. For the course, hygiene and sanitation were the themes for projects. These included a waterstorage and distribution system, a hand washing station, secure trash receptacles and school grounds pathways. Design considerations included the use of local materials, ease of use and sustainability, as well as operations and maintenance. The students developed designs and construction plans that detailed the materials required, quantity and cost estimates, a project schedule, a resource utilization plan and a daily safety plan. This paper provides a background on service learning, describes the course development and implementation, highlights the impact this experience had on the students, presents qualitative assessment data from the experience and illustrates how other programs can participate in such learning experiences.

Improving the Internship Experience: Creating a Win-Win for Students, Industry and Faculty
Christine M. Fiori and Annie R. Pearce
pp. 1398-1408 (11 pages)
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Student internship programs in the construction industry are mutually beneficial relationships that foster student growth, enhance academic program relationships with industry partners, and challenge faculty to include current information in their curriculums. In the construction disciplines, real-world experience is essential to the development of well-prepared graduates and

provides students with an opportunity to interact with various levels of construction personnel. The internship program is an integral part of the Building Construction Program at Virginia Tech. Although summer internships are not a mandatory graduation requirement, in 2003 students were presented with the option of applying their internship experience as a for-credit elective class. As part of the class students were required to sign a statement of goals with the company of choice outlining their desired objectives for the nine-week experience. During the internship, students kept a daily diary documenting activities and key benchmarks of their goals. Upon returning to campus in the fall they completed a written report and delivered an oral presentation summarizing the experience. Since 2003, 100% of graduates participated in one summer internship experience and over half enrolled in the credit option. During the summer of 2007, the internship for credit program launched a pilot course that increased student responsibilities during their internship program. Throughout the summer, students were tasked with five assignments that required them to research sustainability practices within their companies. This paper highlights the new program development, defines the revised internship objectives, describes the implementation process and presents the lessons learned.

Improving Course Comprehension through Experiential Learning

<u>Kirsten A. Davis</u> and <u>R. Casey Cline</u> pp. 1409-1418 (10 pages) http://dx.doi.org/10.1061/41020(339)143 Abstract | PDF (1155 KB) | Permissions

This paper discusses a hands-on experiential learning laboratory, which complements the lecture in a Construction Management (CM) materials and methods course. Many CM programs avoid hands-on experiences due to the vocational/technical stigma. However, experiential learning transforms construction concepts that are often abstract and out of context for many students in an exclusively lecture course into tangible objects and processes. The hands-on laboratory reinforces and supplements material covered in = lecture and improves course comprehension by allowing students to learn through discovery. The laboratory aspect of the course also improves leadership, promotes teamwork, and increases student confidence. This paper discusses specific laboratory experiences used and their educational value, student feedback regarding the experiential labs, and lessons learned for CM programs interested in adding or expanding their hands-on learning experiences for students.

Visualization and Multimedia Applications in Cost Estimating

Education
Saeed Karshenas

pp. 1419-1428 (10 pages)

http://dx.doi.org/10.1061/41020(339)144

Abstract | PDF (589 KB) | Permissions

This paper discusses a software system designed as a teaching tool for construction cost estimating education. The software creates 3D models of Revit designs. The 3D models can store multimedia information for each building element for future retrieval. A user while navigating a 3D model of a building can select an element and view estimating information, video segments of similar elements during construction as well as geometry and material information for the element. The 3D model is also able to interface with Microsoft Excel for cost estimating and with Microsoft Project for scheduling and 4D visualization. The paper discusses how the application streamlines access to building construction information and supports implementation of problem-based learning in cost estimating education.

- Work Experience Impacts on Construction Management Students'
- Cognitions Related to Construction Waste Recycling

  MaryEllen C. Nobe

  pp. 1429-1438 (10 pages)

  http://dx.doi.org/10.1061/41020(339)145

  Abstract | PDF (395 KB) | Permissions

Constructors can significantly impact the sustainability of a construction project through the implementation of construction waste recycling programs (CWM). Prior research, however, has identified a lack of implementation of waste recycling programs due to general contractor's unfamiliarity with and commitment to such practices. Educators are responding by incorporating principles of sustainability into undergraduate curricula. The results from this study, however, suggest that early work experiences may - be counter to education efforts in this area. Senior construction management students who had two to three time the work experience of junior students were less willing to participate in CWM programs. Additionally, the senior students were more likely to have less favorable cognitions (i.e. value orientations, attitudes and norms) and behavior intentions toward construction waste recycling. These results are significant to an industry that is trying to become more sustainable and the educational institutions that are striving to provide environmentally literate graduates.

- Key Skills for Graduating Construction Management Students A
  Comparative Study of Industry and Academic Perspectives
  Rizwan U. Farooqui and Syed M. Ahmed
  pp. 1439-1448 (10 pages)
  http://dx.doi.org/10.1061/41020(339)146
  Abstract | PDF (388 KB) | Permissions
  - This research attempts to determine the extent of agreement between industry and academia as to the required key skills from graduating construction management students, both undergraduate and graduate level, in order to identify any differences in perspectives. This is indeed important in order to develop a strategic plan for construction management educators with specific curriculum improvements so as to prepare construction

management students for the contemporary construction industry. As such, the study endeavors to provide insights into possible future directions undergraduate and graduate construction management education might be heading for and highlights some of the priorities that should be part of the movement. An important conclusion from the study is that skills ranked high by the industry, including interpreting contract documents (for both undergraduates and graduates), listening ability/giving attention to details (for undergraduates), time management (for undergraduates), construction accounting (for graduates), value engineering/ constructability analysis/ design review (for graduates) and contract negotiations/ conflict resolution (for graduates) are given lesser significance by the educators. Hence, these skills signify areas that may require strategic curriculum improvement. Consequently, a collaborative effort to strategically assess and improve construction management curriculums is highly recommended.

Research Validation in the Construction Domain

Gunnar Lucko and Eddy M. Rojas pp. 1449-1458 (10 pages) http://dx.doi.org/10.1061/41020(339)147 Abstract | PDF (388 KB) | Permissions

Validation of the research methodology and its results is a fundamental element of the process of scholarly endeavor.

Construction engineering and management research has various methodological approaches, including surveys and observational studies, modeling and simulation, experiments, theory building, case studies, and other types. All of them required validation. This paper reviews techniques for internal, external, and face validation, illustrates them with examples from construction research, analyzes their challenges, and presents how they were successfully overcome to provide readers with recommendations to properly validate their own research efforts. It thus increases the awareness of the paramount role of validation in scholarly work.

Research Methods Associated with Situational Simulations in

Construction
Amlan Mukherjee, Nilufer Onder, and Eddy M. Rojas
pp. 1459-1468 (10 pages)
http://dx.doi.org/10.1061/41020(339)148
Abstract | PDF (1206 KB) | Permissions

Situational simulations create temporally dynamic clinical exercises of construction project scenarios that expose participants to rapidly unfolding events and the pressures of decision-making. They further construction research and education, by providing an interactive simulation platform that can be used to explore "what-if" construction scenarios, estimate risks and contingencies, test alternative plans during construction, and support the capture and analysis of real-time project data to support expert decision-making. The design, development, and use of situational simulations calls upon an inter-disciplinary approach which includes methodologies that are rooted in modeling of discrete

event systems, intelligent planning, statistical data mining and cognitive psychology. We trace the development of two related situational simulation systems, the Virtual Coach and the Interactive Construction Decision-Making Aid (ICDMA) that have been developed by research groups at University of Washington and Michigan Tech. with technical support from industry. Over the last five years, the simulations have significantly evolved in their abilities to represent and reason about construction projects, as tools that enhance construction education and as experimental test beds that can be used to study construction decision-making. The research efforts have resulted in different aspects of this research to be funded by two funding agencies.

Constructing Research with Case Studies

J. E. Taylor, C. S. Dossick, and M. J. Garvin
pp. 1469-1478 (10 pages)

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A case study is an empirical inquiry that investigates a contemporary phenomenon within its real-life context. The case study research method is popular across various disciplines, however, critics of the method argue that results from this form of research are applicable only to the case studied and cannot be generalized further. In the field of construction engineering and management, the number of papers employing case study research methods over the past decade has increased substantially. The question that arises as the method proliferates is whether case studies are being performed with sufficient validity and reliability to maximize the extent to which the findings can be generalized. Given the unique, project-based nature of the construction industry, in this manuscript, we discuss research design and data collection strategies construction engineering and management researchers can employ to improve validity, reliability and the extent to which they can generalize from their findings.

Techniques for Evaluating Automated Knowledge Acquisition from

Contract Documents

Mohammed Al Qady and Amr Kandil

pp. 1479-1488 (10 pages)

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Abstract | PDF (400 KB) | Permissions

Knowledge Management (KM) has become the focus of a lot of scientific research during the second half of the twentieth century as researchers discovered the importance of the knowledge resource to business organizations. Recent research recommended the use of semantic representation of knowledge that is expressed in natural language to enhance knowledge management systems (KMS). In order to address this need, the CRISP technique (Concept Relation Identification using Shallow Parsing) was developed utilizing a natural language processing tool for extracting concept and concept relations from construction contract documents. The extracted concepts and relations are then used to develop semantic

representations of the important knowledge expressed in the documents. The process of knowledge extraction from textual documents is, however, a subjective task that may differ from one person to another. This paper presents the two evaluation methods used to compare the performance of the CRISP technique with human evaluators. In the first method, Kappa was used to measure the level of agreement of human evaluators on the concepts extracted from an evaluation set, and the level of agreement between human evaluators and CRISP on the same evaluation set. In the second method, a Gold Standard was developed from the results of the human evaluators and precision and recall for CRISP and the human evaluators were calculated based on the Gold Standard. F-measure was used to combine precision and recall and to consequently compare between the performance of CRISP and the performance of the human evaluators. Results from both evaluation methods were relatively comparable.

Techniques to Minimize Bias When Using the Delphi Method to
Quantify Construction Safety and Health Risks
Matthew R. Hallowell

pp. 1489-1498 (10 pages)

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The dynamic and transient nature of construction projects makes construction engineering and management research particularly challenging. For example, experimental research on safety, risk management, innovation, and technology forecasting is often unrealistic due to the sensitivity and complexity of these topics. The Delphi technique, originally developed by the Rand Corporation to study the impact of technology on warfare, allows researchers to maintain significant control over bias in a well-structured, academically-rigorous process using the judgment of qualified experts. The Delphi method is particularly useful when objective

- experimental research is unrealistic or unethical, or when the heterogeneity of the participants must be preserved to assure validity of the results. In this paper, the authors review eight forms of bias that literature in the field of social psychology identifies as detrimental to judgment-based studies such as the Delphi method. Additionally, several techniques are reviewed that should be incorporated into the Delphi method to control for the identified biases. Special attention is focused on the use of these techniques when using the Delphi method to identify and quantify construction safety and health risks.
- Opinion-Based Research: Lessons Learned from Four Approaches
  David N. Sillars and Matthew R. Hallowell
  pp. 1499-1508 (10 pages)
  http://dx.doi.org/10.1061/41020(339)152
  Abstract | PDF (522 KB) | Permissions
  - Selecting an appropriate research method is a critical step in any rigorous research effort. The selected research methodology

impacts the data collected, the scope of inference, and the ability to draw defendable conclusions. Many times the nature of the construction industry and the sensitivity of information limit researchers' ability to conduct experimental, empirical, or observational studies that rely on objective data. In such circumstances, alternative methods of research that utilize expert judgment and opinion may be considered. Several techniques such as group-brainstorming, the Delphi method, the Nominal Group Technique, and surveys may be appropriate. However, selecting one or more of these research methods depends largely on the nature, resources, and limitations of the research study. This paper reviews four major approaches of obtaining expert opinion, describes lessons learned on four independent, major studies, and provides a framework to consider when selecting a specific method given project characteristics. The resulting flowchart can be used to aid in selection of a research method given the specific characteristics of the study such as limitations in time and funding, desired information, and location and availability of participants.

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