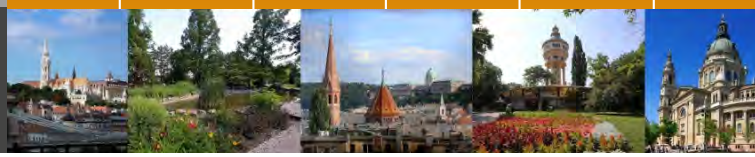
CCC2019

CREATIVE CONSTRUCTION CONFERENCE

29 June - 2 July 2019 | Budapest, Hungary



Final Program & Book of Abstracts

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Creative Construction Conference 2019

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FINAL PROGRAM *(Including page references)*

Saturday - 29 June 2019		
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Lean Construction = Systematically Unleashing Creativity

Iris D. Tommelein

P2SL Project Production Systems Laboratory, Civil and Environmental Engineering Department, University of California, Berkeley, CA, United States

Lean Construction emerged in 1993 as a term referring to holistic thinking about construction, considering Transformation, Flow, and Value in unison. Researchers and practitioners in the field think of construction in its broadest sense (e.g., cradle-to-grave projects, project portfolios, supply chains, markets, and the industry more globally) and have been working on shaping a body of knowledge specific to the delivery of project production systems. Principles and methods from the Toyota Production System have been embraced in Lean Construction, adapted to suit project delivery challenges, and further augmented them with existing methods as well as methods newly-developed to suit.

The creativity that is going into rethinking construction with Lean mindset is integral to the systems thinking that Lean promotes. In this keynote, I will offer examples of this Lean Thinking that drives creativity, which I see as being part of the continuous improvement process that is so fundamental to Lean.

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Preventing the Collapse of Reinforced Concrete (RC) Structures, and Support Work During Construction

John J. Smallwood

Nelson Mandela University, Port Elizabeth, South Africa

In recent years, there have been a spate of collapses in South Africa, in terms of buildings, slabs, and support work. Given this, a study was initiated to determine, inter alia, the importance of factors relative to preventing the collapse of RC structures during construction, and optimum support work and formwork and the integrity of structures under construction.

The study reported on entailed a self-administered survey of a convenience sample of six (6) 'better practice H&S' general contractors (GCs), a construction project management practice, as well as alumni of a South African university.

In terms of preventing the collapse of RC structures during construction, and optimum support work and formwork and the integrity of structures under construction, it can be concluded that the requisite 'cocktail' of factors must be in place and to an optimum extent. Competencies, design, registration of built environment professionals, HIRAs, supervision, quality management, H&S management, risk management, planning and H&S planning in various forms; integration of design and construction; the construction work permit; a range of support work aspects; inspections, circumspect loading, and conformance to requirements are all important as clusters or individually.

Recommendations include that conformance to requirements is the key, that such recommendations be scientifically evolved and communicated, a pre-requisite being that the required competencies exist, which can only be assured through a formal registration process, including that of contractors. Ideally, multi-stakeholder project H&S, quality, and risk plans should be evolved, and design and construction must be integrated. Then, general construction management and H&S planning must be a hallmark of all projects, and then optimum management and supervision to ensure execution of such planning.

Keywords: *Collapses, Construction, Structures*

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How Artificial Intelligence Will Shape the Future of Construction

Wen-der Yu

Department of Construction Engineering, Chaoyang University of Technology, Taichung, Taiwan, Republic of China

Artificial intelligence (AI) has been changing our lives for decades, but never has AI felt more ubiquitous than now. The recent development of Artificial Intelligence (AI), especially the deep learning neural networks (DLNN), has demonstrated their capability to defeat most intelligent humans in playing Go games. It is expected to impact our future in every aspects. The construction discipline is not an exception. AI applications in construction engineering and management have experienced prosperous development during 1990~2000. The booming development faded after 2000 due to the limitation of computational capacity of computer. The new generation of AI development resumed since 2006 when the Graphic Processing Unit (GPU) was adopted as simple massive processing units for parallel computations. In 2012, with the new computational algorithms of DLNN, a new wave of AI applications for processing of the bid data in image recognition, natural language processing, and speech recognition has shown the dramatic potentials to impact the human lives including construction engineering and the way of engineering education. In this talk, the most advanced developments AI applications in construction engineering and management will be demonstrated with real life examples. Some most adventurous projects will be explored to probe the inevitable impacts of AI to the construction industry.

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Quality, Innovation and Environment Protection at Europe's Largest Cultural Development Project

Attila Sághi

Városliget Ltd., Budapest, Hungary

The Liget Budapest Project envisions the complete renewal of Budapest's largest and most iconic public park, Városliget (City Park). Városliget has offered a unique mixture of natural green environment and institutions of leisure, entertainment and culture for more than hundred years for those visiting the park and the general goal of the Liget Budapest Project is to carefully transform and enhance these amenities into a new form to meet the expectations of the twenty-first century.

Városliget's strong heritage of mixing cultural functions with green areas is a strong foundation of Liget Budapest Project. To create a future-proof project based on this heritage an international approach had been followed during design process. Architects for all major buildings had been selected via a series of international design competitions with a world-class jury. Winners of each competition suited the best for the multi objective goals of architecture, sustainability and functionality.

Liget Budapest Project will receive BREEAM Excellent certifications for all the new buildings, and at the same time the Project as a whole will be certified in BREEAM Communities scheme. To comply with these high standards many sustainable solutions have been introduced such as LCA material optimization, comprehensive energy and water strategy including the use of waste water heat of the existing baths, 95% construction waste recycling, comprehensive lighting design strategy to minimize light pollution, use of local materials, etc The organization of construction work and the measures related to the mitigation of environmental impact may be limited primarily by the usual procedures and regulations.

Keywords: *Liget Budapest Project, BREEAM, Quality Innovation, Environment Protection*

30 June 2019, 9:45-10:45

Creative Management:
Zoltán A. Vattai

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A Multi Objective Scheduling Model for Minimization of Construction Project Duration, Total Cost and Environmental Impact

Ahmed Senouci[a], Urjita Nitin Bowlekar[b], SeyedAmirhesam Khalafi[c] and Neil Eldin[c]

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The performance of construction projects has traditionally been measured based on cost, time, and quality. Recently, the environment impact has been introduced as a fourth criterion for the assessment of project performance. Significant research advancements have been made in the area of optimizing resource utilization to minimize the total cost, duration, and quality for construction projects. A number of models have been developed using a variety of methods, including heuristics methods, mathematical programming, genetic algorithms, ant colony, and particle swarm optimization. However, there has been little or no reported research focusing on studying and optimizing the collective impact of resource utilization decisions on construction cost, duration, and environmental impact. The objective of this paper is to present the development of a multi-objective optimization model for optimizing resource utilization and scheduling of projects. The model provides construction planners and decision makers with new and important capabilities, including: (1) evaluating the combined impact of multiple resource utilization decisions on construction cost, duration, and environmental impact and (2) generating and visualizing optimal/near-optimal resource utilization and scheduling plans that provide optimal trade-offs between the project cost, duration, and environmental impact. The model is developed in two stages: (1) model formulation to identify the decision variables and optimization objectives for the construction optimization problem and (2) model implementation to perform the optimization computations using three modules that compute project duration, total cost, and environmental impact, respectively.

Keywords: *Multi Objective Optimization, Environmental Impact*

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Application of Artificial Intelligence to Automate Construction Materials Data Classification

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The applications of Big Data analytics and Artificial Intelligence (AI) have gained a widespread attention in the construction industry in recent years following the promulgation of Industry 4.0. In the realm of construction research, AI has been utilised widely in areas such as structural design optimization, resource and equipment planning, and project scheduling. The research presented in this paper is aimed to utilise AI to assist with the automatic classification of the large volume of construction material orders created by users through an online marketplace website. Such big data of material orders contained numerous errors (e.g. typographical errors and incorrect units) that were extremely time consuming to correct before the datasets can be used to for further business intelligence analysis. In this research, the dataset was obtained from a business-to-business e-commerce company in Thailand, namely BUILK. The data from BUILK was the construction materials purchase orders created by BUILK's customers through its website, which contained hundreds of thousand unorganized records. In this study, Artificial Neural Networks (ANNs (was applied to automate the categorization of approximately 220,000 records of reinforcement steels orders. The ANNs model was developed and trained using over 32,000 records, with approximately 92 percent of prediction accuracy. The model automatically categorized the steel reinforcement data into 11 groups; Deformed Bars, Round Bars, Wire mesh (Deformed Bars), Wire mesh (Round Bars), Stirrup, Anchor, Material and Others. The outcome of this research helped the company to easily analyze the data to generate insights for its business management and development.

Keywords: *Artificial Nearal Network; Big Data; Business Intelligence; Construction Materials; Purchase Orders; Thailand*

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Supply Chain Management in the Ghanaian Building Construction Industry: A Lean Construction Perspective

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Supply Chain Management (SCM), for the past two decades, has been identified by manufacturing industries as a new way of doing business. Construction, just like the manufacturing and other services industries, is experiencing emerging trends that are aimed at giving ultimate satisfaction to the end user. Lean Construction is a way to design production systems in order to minimize waste of materials, time, and efforts that generate maximum possible amount of value. This research looked into how supply chain management can benefit the Ghanaian building construction industry through the application of lean concept. The purpose of this study is to assess the level of collaboration and coordination in planning of activities among construction industry players, and investigate into the sources of waste in construction. The study is considered as qualitative case study. Data is collected through questionnaires, in depth interviews and direct observation of on-going projects on KNUST campus. One sample t test is used to analyze the data. The findings pointed out that the level of coordination and collaboration in planning among industry players were very appreciable though there still exist room for improvement.

Keywords: *Construction; Lean; Supply Chain Management; Value; Waste*

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Value Methodology in the Real Estate Practice

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Value Methodology (VM) is a management consultancy methodology that dates back 60 years. According to its definition, value is the ratio of function and resources. VM is a complex decision-support procedure that takes the consumer's need as a starting point and, in order to reach the technical-economic optimum, analyses and shapes the relationships between the functions and costs of a product in a constructively critical manner, as part of team work, in the course of a closely monitored process to create a more favorable value. VM is widely used in various industries, including the construction industry. The methodology is also successfully applied in production processes in Hungary. However, it is striking that the use of VM is not common in segments related to real estate consultancy.

This article examines the possible role of VM in the real estate practice, using the method of requesting expert opinion in a training program. The survey clearly shows that both the whole of the methodology and certain of its elements could be included in the everyday practice of real estate experts.

Keywords: *Value Methodology, Value Engineering, Real Estate, Real Estate Valuation*

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Automation and Robotics in Construction:

Mirosław Jan Skibniewski

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Cyber Security Challenges and Vulnerability Assessment in the Construction Industry

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The construction industry is making a shift towards digitization and automation (known as Construction 4.0) due to the rapid growth of information and communication technologies as well as 3D printing, mechatronics, machine learning, big data, and the Internet of Things (IoT). These technologies will transform the design, planning, construction, operation and maintenance of the civil infrastructure systems, with a positive impact on the overall project time, cost, quality, and productivity. These new technologies will also make the industry more connected, and the consideration of cybersecurity of paramount importance. Although many studies have proposed frameworks and methodologies to develop such technologies, investigation of cybersecurity implications and related challenges have received very less attention. Some work has focused on security-minded BIM, but it lacks generality or does not consider an approach to determine the vulnerability of the different project participants, construction processes, and products involved during the different phases of construction projects. To address these limitations, this study a) develops a framework to identify cybersecurity risks in the construction industry, and b) assesses the vulnerability of traditional and hybrid delivery methods based on an agent based model (ABM). That is, the vulnerability of different project participants and construction entities during the different phases of the life-cycle of construction projects as a consequence of Construction 4.0. The findings from this study help to identify potential risks and provide a basis to assess the impact of interactions in a digital environment among different project participants. Future work aims to thoroughly investigate the proposed ABM approach and extend the same to other project delivery methods and information exchange networks in construction projects.

Keywords: *Agent Based Modeling; Construction 4.0; Cyber-Physical Systems; Cybersecurity; Smart Construction Sites; Vulnerability Assessment*

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Exploiting Automated Technologies for Reduction of Rework in Construction Housing Supply Chain

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Housing has been experiencing significant rework within the supply chain. Rework has afflicted both cost and schedule of projects due to the complex environment, intricate activities and highly fragmented nature of housing supply chain. Housing supply chain generate immense data and share information with different parties, which contribute to multitude of countless challenges. As a result of rework, productivity and workflow of information in construction supply chain has been affected with a catalogue of problems for the past few decades. Automation in construction supply chain with novel technological and analytical strategies has aspired industry to improve the productivity and change the trajectory of traditional, manual and analogue way of processing. The aim of this study is to explore possible opportunities of employing new technologies and challenges involved in utilising automated technologies for minimising rework in housing supply chain. The research methodology is based on a review of literature to investigate automated technologies to eliminate rework in housing supply chain. A conceptual framework is proposed to determine the suitability of various technologies to fully automate housing supply chain and facilitate the reduction of rework in construction housing supply chain.

Keywords: *Automated Technologies; Housing Supply Chain; Offsite Manufacturing; Robots; AI; Reduction of Rework*

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Conceptual Design of Controllers for Sutomated Modular Construction Machines

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Without a methodology, the practice of control system design for automated modular construction machines mainly depends on experience and trial-and-error. Implementation of controllers requires planning at the conceptual design phase. Axiomatic design (AD) has been introduced in developing control solutions. This paper formalizes the conceptual design methodology in building a controller with the use of quality function deployment (QFD) as a design and an analysis tool. The controller design approach using QFD has been applied to the automated steel wall framing machine and to a 2-degree-of-freedom (DOF) robotic arm, which can be readily extended to n-DOF robotic manipulators. The analysis and decoupling techniques for controller design presented in this paper differ from those used in traditional AD. QFD for controller design provides continuous transfer functions to represent relationships and mathematical decoupling that is easily implemented in software.

Keywords: *Controller Design; Decoupling; Modular Construction; Quality Function Deployment; Robotic Manipulators*

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A Roadmap to Achieving Readiness for Macro Adoption of Distributed Ledger Technology (DLT) in the Construction Industry

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Applications and uses cases of distributed ledger technology (DLT) are increasingly attracting interest in the construction industry. However, DLT in construction is still considered a nascent field of research and practical applications of DLT in construction are at the very early readiness stages. This paper builds on a previously developed socio-technical systems framework for DLT in construction (i.e. Li et al., 2019) built on four dimensions of technical, process, policy and social, and proposes a roadmap to achieving readiness for macro adoption of DLT in the construction industry. First, the paper reviews existing readiness and adoption models and technology roadmaps for new technological innovations in the context of DLT highlighting their strengths and detailing why they are not suitable for DLT. Then, drawing on experience of existing models as a basis, it proposes a four-stage roadmap to readiness for adoption of DLT in the construction industry. The four-stage DLT Roadmap incorporates Conceptualisation, Appraisal, Preparation and Implementation. This roadmap is intended to provide the industry with a comprehensive framework to support adoption and diffusion of DLT for specific use cases. Future work will involve proposal of guidelines for each of the four dimensions across the four-stage DLT Roadmap and testing through workshop-identified use cases of DLT in construction.

Keywords: *Distributed Ledger Technology (DLT); Blockchain; Technology Roadmap; Macro Adoption; Readiness; Construction Industry*

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Sustainable Construction, Health and Safety:

Miklós Hajdu

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The Transportation Management Framework for the Polokwane Local Municipality During the Zion Christian Church Easter Weekend Pilgrimage

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The high volume of traffic to the Holy City of Moria during the Easter weekend could be graphically described as taxing to both the motorists and pilgrims. The rationale for the study was to understand, investigate, analyse and describe the role of the Polokwane Local Municipality (PLM) in the planning and the execution of the Zion Christian Church (ZCC) Easter weekend pilgrimage with a view to reducing vehicular traffic. The PLM is home to the Zion Christian Church (ZCC), that hosts one of the biggest mass gathering event on the African continent, but researchers and the media have paid little or no attention to this pilgrimage which attracts more than 15 million pilgrims during the Easter weekend. It is notable that a mass gathering is an event attended by enough people to strain the planning and response resources of a community, state or nation. The researchers adopted an action research strategy with the view to carving out a lasting solution to the management of the high volume of vehicular traffic during the Easter weekend pilgrimage. Judgemental or purposive sampling was chosen over other available sampling methods due to the few experienced municipality employees who work closely with the church in the planning of the pilgrimage. Eight themes emerged during the interaction between the researchers and the municipality. The study graphically showed that there was a lack of synergy between the ZCC and the municipality in the execution of the pilgrimage. The research findings suggested that; traffic congestion was attributable to a vehicular-centric approach to transport planning in South Africa. The heavy reliance on vehicular transportation by South Africans is a cause of road accidents. The study recommended an introduction of a pilgrim train for the church with a view to reducing vehicular traffic congestion during the Easter weekend pilgrimage for the collective good of both the motorists and the pilgrims.

Keywords: *Cooperation, Execution, Infrastructure, Planning, Services and Stakeholders*

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Measures to Regain Productivity after Construction Accidents

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When construction accidents occur, besides the direct impact on the victims, there may be collateral effects on the remaining/uninjured workers. In the context of the aftermath of accidents on construction sites, this research investigates the extent to which the uninjured workers' productivity is affected; and uncovers the more effective measures to be instituted on workers after witnessing construction accidents so as to prevent further loss of their productivity. A questionnaire survey was conducted on randomly selected construction professionals who had been supervising workers when and after accidents took place on construction sites in Singapore. The data collected were analyzed using the SPSS software. The first finding is that workers' productivity and wellbeing fall significantly after witnessing construction accidents. They have lower morale, are distressed by the accident and stressed by having to take on additional work or accelerate their work after construction resumes on site. This research found that while a worker's wellbeing deteriorates significantly in the aftermath of a construction accident, there are upsides to construction accidents too. Workers are observed to adopt better work attitude and have higher sense of safety after construction accidents. Significant positive correlation is found between workers' wellbeing and their productivity. The second finding is that the workers turn to fellow workers and supervisors for support post accidents. Relieving them from duties are also effective measures to alleviate the psychological effects of the accidents. The study found that to minimize the negative effects of construction accidents, contractors should improve site safety swiftly, offer employee assistance program, relieve workers from regular duties temporarily and refrain from overloading them after work is allowed to resume. It is recommended that supervisors avail themselves to the workers, for example, through mass psychological debriefing or one-to-one counselling.

Keywords: *Accidents; Morale; Productivity; Safety; Wellbeing*

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Employing Generative Design for Sustainable Construction

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Generative design is the alteration of an object's shape to optimize its function. Currently, the scope of generative design is limited in the structural civil engineering field. Structural design still follows conventional methods compatible with conventional construction processes. These processes restrict the flexibility in design resulting in structural elements having excess materials to satisfy critical structural capacity requirements. This introduces additional costs and higher environmental impacts. New tools, such as concrete and steel 3D printers, are emerging to enable more complex geometries in construction allowing higher flexibility in design options. Inspired by the above, this paper aims at developing a design engine that provides optimal design solutions to reinforced concrete beams with sufficient structural capacities while using less materials and resources. Based on ACI code design guidelines, a cantilever beam was structurally analyzed to relate geometry parameters to structural capacity. Optimization was achieved by minimizing the depth and the steel reinforcement ratio at each segment along its length. Hence, concrete and steel at each location would take their optimal quantities. This results in lighter and more economic structures conforming to the structural capacities required by the codes. The engine is based on three objective functions that solve for the minimum values of beam depth and reinforcement at each section which optimize cost and CO_2 emissions individually or simultaneously. MATLAB was used to design the optimized beam and to calculate the percentage decrease in cost and CO_2 emissions between the optimized and conventional beam. A significant reduction ranging between 40% and 52% of cost and between 39% and 51% of CO_2 emissions per beam is achieved. If the design engine developed was utilized in parallel with the 3D printing construction method, structures with optimized quantities, materials, and shapes would be developed. Thus, minimizing drastic effects on the environment and achieving reduced costs.

Keywords: *3D Printing Construction Method; CO_2 Emissions Optimization; Cost Optimization; Generative Design; Structural Analysis*

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A Study on a Conceptual Data Model for Developing a Building Fire Information Management System

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Recently, as large-scale indoor fires have increased, fire-response systems that enable systematic and effective responses have become more important. Despite the need for the quick and intuitive gathering of relevant information for effective fire response, current information transmission systems are based on paper documents and the opinions of the people nearby. These actions can delay the response time and often cause inappropriate judgments. For an effective fire response in a building, it is important to quickly and intuitively collect and provide relevant information such as location data, available fire equipment, and risk factors in the event of a fire. Building Information Modeling (BIM) can be used in various ways from 3D visualization to spatial data management. Despite these advantages, utilizing data stored in BIM remains a challenge for emergency responders who respond directly at fire sites. This study aims to propose information requirements and conceptual data structure for the development of BIM based building fire information management system for fire response. This can store management history data and build a database so that the required information can be delivered quickly in case of a fire. Based on this paper, the proposed building data structure is expected to design a data model for the construction of the fire related information system database in the field of building disaster management. In future research, a system prototype will be developed with this conceptual model and its effectiveness will be verified by applying it in actual practice.

Keywords: *Fire Responase; Data Model; Data Management; Building Infomration Modeling (BIM)*

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Creative Management:
István Vidovszky

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A Novel Model for Contractor Selection Decision

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The prevailing practice on the owner's decision of contractor selection method for a procurement project has been determined by the top manager of the procurement agency via her/his comprehensive consideration of all affecting factors. Although previous researchers have proposed some analytic models to assist the decision of contractor selection method, the procurement personnel usually tend to adopt Lowest Tender (LT) for contractor selection to avoid violation of the regulation for 'Abuse of Public Power for Private Profit' without a no clear evidence to support the adoption heterogeneous procurement method (HPM), e.g., Best Value (BV) or Heterogeneous Lowest Tender (HLT). Moreover, all previous contractor selection analytic models employ the post-tendering data, it is impossible to be applied for pre-tendering decision making. To improve this drawback, the current paper proposes a Pre-tendering Graphic Analytic Model (Pre-GAM) that builds the required graphical analytic model for decision of contractor selection method using a special standardization method for historical bidding data. A real-world building construction project is adopted to demonstrate practical application and to show that the proposed Pre-GAM is able to improve the problem of post-tendering analysis and determine the correct contractor selection method.

Keywords: *Heterogeneous Procurement, Graphical Analysis Model, Standardization, Bidding Data*

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Validation of Support Tools for Project Management: Case of COPPMAN

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Project managers have started to draw support from IT solutions to handle projects, which are more complex than before. Therefore, most of the companies have been generating solutions specific to their need in addition to available software for general use. Any designed product/software requires a testing process not only to check that it is correctly working (verification), but also to secure that it is successfully serving for the intended purpose (validation). To ensure validity, new trend in software development has become early interaction of the possible users of the software to the development process to improve product quality. Early evaluations of the users provide detailed probing of the need that supports structuring the design, whereas latter evaluations serve as behavioral analysis of the developed software. Thus, user interaction for validation of software can be integrated to design process life cycle at any level of the process with different purposes and detail of evaluation. This study exemplifies validation study of a construction project portfolio management tool (COPPMAN), which is developed to support construction companies in adopting project portfolio centered management perspectives. Within evaluation studies of COPPMAN, three professionals from a construction company were assigned as a focus group and their evaluations were obtained through discussions and interviews at three main levels of the development process as; needs analysis, model generation, and beta testing. The current study mainly handles the beta testing process, where actual utilization of COPPMAN was made with a sample of nine real construction projects of the company. Evaluations made during and at the end of the process appreciate the potential value of COPPMAN in decision-making at top management level with its expected benefits in “strategic planning”, “business development”, “organizational learning” and “knowledge management”. Suggestions for improvement of COPPMAN were also obtained as possible considerations for the forthcoming update. This validation process acts as a successful complementary to other validation testing processes undertaken in the development cycle (expert evaluation, pilot testing and usability testing) by providing a real environment(/in-house) evaluation as a trial of actual utilization of COPPMAN.

Keywords: *Construction Industry; Decision Support System; Project Portfolio Management; Software Testing; Validation*

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Improved Unbalanced Bid Detection Model

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Detection of unbalanced bids is crucial for owners because selecting an unbalanced bidder as the contractor may bring about cost overruns. There are two main types of unbalanced bids, namely, mathematically and materially unbalanced bid. This study mainly focuses on the second type, where a contractor tends to increase the unit prices of items whose quantity was somehow underrated by the owner's team. This study proposes a modification to a model that was developed to assist owners in detecting unbalanced bids. The major difference between the proposed model and the previous one lies in the grading system of detecting the unbalanced bids. In the proposed model, eight different grading systems are used in detection of unbalanced bids, whereas the previous model consisted of five grading systems. The final score of each bidder is calculated by assigning weights to these grading systems. Bidders are evaluated not only according to the offered bid prices, but also according to the calculated final scores. The applicability of the proposed approach is presented along with an illustrative example. It was observed that the proposed model detected the unbalanced bid, which attains the lowest final score. The proposed model represents a marked improvement on existing practice and provides owners with a new perspective in detecting unbalanced bids. Armed with such a tool, it may be easier for owners to protect themselves from the risk of unbalanced bids.

Keywords: *Unbalanced Bid; Detection Model; Grading System; Owner; Case Study*

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System Adjustments through Vector Organization and Technology

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The production system is in the function of the organization and the technology of an implied system. The organization is the function of the structure and the flow, which in turn defines the unity of the arranged interrelated elements. The use of new technologies, especially the ones from the realms of computer science and cybernetics, and integrating them into the building industry technologies provides for enhancing the building industry business flow indices. The existing organization structure is thus to be supplemented with adjustment tool which is inevitable for systems and provides for business systems to feature the resources/days –based levels of control over projects. IIS technology has thus turned the matrix organization structure of the building industry into the vector one.

The discrete norm elements should be replaced by the vector norm elements for the purpose of speeding up the technologic processes of planning and norm defining that are in turn the motors of companies providing for the deployment of he implied controls (system adjustment, that is); in other words, it means that the BIM business system – or the whole system as well- should be modeled. By means of further modeling and the BIM system simulations, there emerges the building industry business DSP model within the micro unit. The DSP method (dynamic structured programming)) integrates the dynamic and the structu8red programming and provides – for the time being.-for a dynamic modeling of structures and the flow through the formula within the vector system; as to the future, it will provide for defining the organization differential by means of iterating multidimensional model structure.

Keywords: *Vector Organization; Vector Norm; Daily System Adjustments; BIM and DSP Models; Organization Differential*

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Industry 4.0 and Construction Supply Chain Management

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Industry 4.0 has contributed positively to establishing digital value-added supply chains to enable information flow between environment, clients, business partners and products. The aim of this article is to present a review on the features, elements and role of industry 4.0 to construction firms supply chain management. This article further reiterates the importance of digital industry 4.0 in construction firms supply chain management, especially on how construction industries and stake holders can reduce project delivery time, material and labor costs. The article reveals that industry 4.0 will have a high significant effect on the future of construction supply chain if it can identify crucial elements for improvement, such as speed, adjustability, measure of productivity, and high-test quality. The article also suggests further comprehensive research on how technological advancement can bring global competitiveness of the construction industry supply chain.

Keywords: *Supply Chain Management; Construction; Industry 4.0; Global Competitiveness; Information Flow*

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Visualization, BIM:

Borja Garcia de Soto

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Deep Learning-based Vehicle Image Matching for Flooding Damage Estimation

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Images representing flooding damages can provide valuable information, such as the damage location and severity. Automated and quantifiable analyses of those images allow asset managers to accurately understand the vulnerability of the infrastructure. To this end, this paper proposes a methodology to match a vehicle in a flooding image to a 3D vehicle image. The proposed method is a part of a framework for flooding depth estimation. As the initial step of the framework, the proposed method uses Mask R-CNN and VGG network to extract the vehicle object and its features, respectively. The features of the vehicle images are compared with those of 3D vehicle image, to find a good match. A total of 87 vehicle objects were used to validate the proposed method, and promising levels of matching accuracy were obtained. Once the framework is completed, the proposed method is expected to automatically analyze flooding images for its damage assessment.

Keywords: *Flooding Damage; Vehicle Image; 3D Vehicle Image; Image Processing; Deep Learning;*

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Lifecycle Design of Fastening Systems in Concrete Supported by BIM: Case Study Subsequent Assembly of an Industrial Robot

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In the last years, particular focus has been devoted to the life cycle performance of fastening systems, which is reflected in increasing numbers of publications, standards, and large-scale research efforts. Simultaneously, experience shows that in many cases, where fastening systems are implemented – such as industrial facilities – the design of fasteners is governed by fatigue loading under dynamic characteristics. In order to perform an adequate design and to specify the most efficient and appropriate fastening product, the engineer needs to access and process a broad range of technical and commercial information. Building Information Modeling (BIM), as a data management method in the construction industry, can supply such information and accommodate a comprehensive design and specification process. Furthermore, the application of BIM-based processes, such as the generation of a BIM-model, allows to use the important information for the construction as well as the life-cycle management with different actions and time dependencies of the asset and its components. As a consequence, the BIM model offers the potential to correlate different data relevant for achieving the goals of the respective application, in order to ensure a more effective and correct design of the fastening. This paper demonstrates such a BIM-based design framework for an Industry 4.0 case, and in particular, the installation of a factory robot through post-installed anchors under fatigue relevant loading in concrete.

Keywords: *Building Information Modeling; Fastening Systems; Fatigue Loading; Industry 4.0; Lifecycle Design*

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Allocating BIM Service Cost—A Taiwan Experience

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Benefits of BIM application in building construction projects have been reported by many previous researchers, but very few works were done for the guideline of estimating and allocating of the costs of various BIM uses. Without such a guideline, it is difficult for the owner to determine and budget the selected BIM uses. To meet this need, this paper presents a case study on the estimating and allocating the costs of BIM service based on the 25 BIM Uses defined in the 'Taiwan BIM Guide' developed by the Architecture and Building Research Institute (ABRI), Ministry of the Interior (MOI), Taiwan, for implementation of BIM by local construction industry. Appropriate portfolio of BIM Uses should consider the limitation of available resources and specific project characteristics. Only the priority of the 25 BIM Uses need to be selected and budgeted. To estimate and allocate required costs for various BIM uses, the current study proposes a method to determine the relative requirements of costs for different BIM uses by surveying the BIM practitioners from the 10 public social housing projects owned by the Taoyuan City Government using an Analytic Hierarchy Process (AHP) method. A BIM use cost allocation guideline is provided as a reference to the BIM practitioners to determine the required costs for different BIM Uses.

Keywords: *Building Information Modeling (BIM); BIM Guide; BIM use; BIM Service Cost; Analytic Hierarchy Process (AHP)*

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Using Dynamo for Model-Based Delivery of Facility Asset Data

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Large facility owners are becoming increasingly aware of the value and advantage of utilizing design and build teams to capture and deliver facility asset data necessary to populate their Computerized Maintenance and Management System (CMMS) for efficient operation and maintenance of their facilities. Facility asset data can be delivered using various formats including a spreadsheet-based or a model-based deliverable. In a spreadsheet-based deliverable, asset data are captured and stored using a spreadsheet specifically formatted to allow the end user direct linking of the spreadsheet to the CMMS and automatic upload of the data. In a model-based deliverable, asset data is captured and loaded into a BIM model then transferred directly or indirectly from the model to the CMMS using various data exchange methods.

This paper discusses the indirect linking of facility asset data captured in a Revit BIM model to the facility management system through exporting the data to an external database. Dynamo, an open-source script-programming tool that works within the Revit environment, is used to extract and export the data from Revit to an external SQL database in a specific format and organizational structure that would allow for uploading of the data to the CMMS. Dynamo script (e.g. Python script) was used to export certain data parameters in a specific order and format. Exported asset data parameters and values are saved to the SQL database and linked to the CMMS to support operations and maintenance.

The paper uses a case study approach to illustrate the implementation of Dynamo to a renovation project for a large academic institution. Asset data for the project is captured from project plans and submittals and loaded into a Revit BIM model. The Dynamo script is tested to verify the export of data in the required format.

Keywords: *Asset Data; Revit, Dynamo; SQL (Standard Query Language); CMMS (Computerized Maintenance and Management System)*

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Combining BIM and Last Planner on Construction Sites: An Investigation of the Related Challenges

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The construction industry is facing a gradual but important transformation towards more productivity and collaboration. In this framework, two major approaches are often cited in the literature as having the potential to improve the practices in the industry: Building Information Modeling (BIM) and Lean Construction. Several scientific studies have demonstrated the synergy of these two approaches and very recent research has reported positive results from the use of software applications as support for their implementation on construction sites. However, the stakes of such integration have been very little studied. This article presents the results of a research project conducted within a general contractor firm that decided to implement BIM and Last Planner System (LPS) on its construction sites. The research uses a four-stage action research approach, including the characterization of the research issue, the establishment of an action plan, its implementation and its evaluation.

Compared to recent related studies, the research is less enthusiastic. While it highlights the need for new tools to improve production planning and control, it also points to a strong resistance to change by practitioners at the site. They emphasize the necessity for adequate pre-service training and the need for new resources that can work full-time on the ongoing training of site teams. In addition, some limitations of the tool lead workers to believe that it can quickly become a factor that slows down their daily work rather than improving it.

Keywords: *Building Information Modeling; Last Planner System; Construction Site*

30 June 2019, 11:15-12:30

Sustainable Construction, Health and Safety:

John J. Smallwood

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Do Thermal Comfort Standards Ensure Occupant Satisfaction? Learning From Occupants' Thermal Complaints

Ezgi Kocaman, Merve Kuru and Gulben Calis

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Today, buildings are operated according to the standards (i.e. thermal), however; the recommended values in the standards might not necessarily address occupants' needs, and, thus, occupant complaints might arise. This study aims at assessing the performance of the predicted mean vote (PMV) model to detect occupant thermal dissatisfaction. The case study was conducted in a commercial building located in Paris, France between January 2017 and May 2018. Indoor environmental conditions were monitored via sensors and an online tool was used to collect occupant thermal complaints. A total of 53 thermal complaints were analyzed and the corresponding measurements were checked against the reference values suggested by the ISO 7730 Thermal Comfort Standard. The results show that all of the operative temperature measurements both in the heating and cooling seasons were within the thresholds suggested by the standards. In addition, the PMV method suggested that only 4% of the occupants were dissatisfied with the indoor environment. However; the actual dissatisfaction ratio of occupants was 100% under these indoor environmental conditions. The findings of this study show that predefined comfort ranges, and, thus thermal comfort standards are not able to predict occupant thermal dissatisfaction.

Keywords: *Thermal Complaint; PMV-PPD Model; Thermal Comfort; ISO 7730*

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Approaches to Improve the Quality of Workplace Built Environment

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This paper highlights the main factors which can have a positive impact on the productivity of workers within an organization. It talks about the current trends and practices followed by the organizations to improve the quality of the workplace and the need to improve the quality of workplace according to changing demands of occupiers. The study is being conducted with the help of secondary research data exploring the existing work-analysis structures, trends, practices and case studies. Qualitative research methods are used for analyses of the data: Content analysis, previously published articles and papers. In this way, new ways of producing and operating buildings and the imperatives for such a process have been analysed which can help the inappropriate level of user involvement in the building procurement process and the way these buildings and work style in these buildings are managed.

Keywords: *Built Environment; Quality of Workplace; Space Management; Building Environment*

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Dealing with Ageing Workforce in the Hong Kong Construction Industry: An Initial Exploration

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The workforce in the 21st century is ageing. There is increasingly larger proportion of workforce 50 years of age or older. This ageing situation is prevalent in the Hong Kong construction industry as about 41% of total registered construction workers in Hong Kong are 50-year-old or above as at 31 Aug 2018, and the failure of the industry to attract younger workers. These situations have collectively led to serious manpower shortage. Most construction workers are experiencing physically demanding works on a daily basis. Workers are also subjected to constant psychosocial pressures including the need to face stressful environmental conditions, long and sometimes irregular work hours, unpredictable workplaces and conditions, and dis-continual employment. In addition, the organisational and institutional arrangements in Hong Kong construction industry are less supportive in providing favourable working environment for older workers. Despite these misgivings, we know very little of the conditions older construction workers experience in Hong Kong construction industry. There is therefore a need to investigate such issues and propose possible intervention to improve the working conditions of our senior workers. With these objectives, in this paper, we first report the findings of a small scale survey on the care of older workers in Hong Kong construction industry, and second propose potential intervention by combining the findings of the survey and our industry observations of the practices implemented by progressive contracting companies in Hong Kong. In developing the intervention scheme, we draw from the approach of the emerging field of integrated health and safety protection and promotion. The scheme focuses on the relationships and causal pathways of the conditions of works to workers' health and safety outcomes by taking into consideration the organisation and workforce characteristics. It is argued that the framework can potentially mitigate the risks associated with ageing workforce.

Keywords: *Ageing Workforce; Construction Workers Health Safety and Well-Being; Integrated Approach; Protection and Promotion; Working Conditions*

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Smart Wearable Technologies to Promote Safety in Aging Construction Labor

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Societies across the globe are facing aging populations that present significant challenges in the design and construction of high-rise buildings. In the wake of this demographic change particular attention must be paid to an aging workforce's safety on-site and the impact that smart technologies could have in the prevention of accidents from a worker's lack of functional capacity.

This study aims to develop a questionnaire survey to collect the required data on the monitored activities older construction workers perform, and the implementation of this monitoring for the prevention of accidents on-site. Initially, the smart technology that is crucial to the adoption of such an approach will be introduced. Next the history of wearable technologies, both successfully and unsuccessfully applied to elderly users, will be analyzed. Consequently, and drawing on the primary data gathered via the questionnaire, this study will present relevant information from 15 small and medium-sized construction firms. This study uses statistical methods to represent a basic approach towards identifying significant factors from the questionnaire results. Finally, it will be shown that this data will prove useful to researchers, contractors and construction companies within the scope of effectively integrating gerontechnology in the construction stage of projects.

Keywords: *Construction Safety, Gerontechnology, Wearable Technology*

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Sustainable Construction Practices Challenges- A Stakeholders Perspective

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Sustainable construction practices not only benefits government, environment and occupants but it secure the earth for future generations to come. Thus the paper discussing sustainable construction practices challenges in the construction industry of South Africa. Structured questionnaires were distributed to different construction companies and construction professionals. From the 75 questionnaires distributed, 60 were brought back and they were all valid and usable. Findings from the survey results obtained from the chosen respondents revealed that the is a lack of training in an organization regarding sustainable construction, lack of awareness of sustainable construction practices, lack of sustainable environmental materials, changes in material prices and escalations, lack of accessible guidance, lack of technical skills, resistance to change in adoption and material scarcity. The construction industry needs to promote and create more workshops on sustainable construction practices so that more stake holders would be aware of it benefits and incentives should be provided to organization that are implementing sustainable construction. Furthermore, the implementation of construction principles can be achieved successfully if all the construction stakeholders participates from design to completion of the project with the assistance of knowledgeable project manager on sustainable construction practices. The study will contribute to the body of knowledge by increasing more awareness of SC to professionals in order to be implemented.

Keywords: *Challenges; Construction industry; Sustainable Construction; Sustainable Construction Practices (SCPs); Construction Industry; South Africa*

30 June 2019, 14:45-15:45

Creative Management:
István Hajnal

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What are the Barriers and Drivers toward BIM Adoption in Nigeria?

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The 'digitalization and collaboration' or Building Information Modelling (BIM) in the construction industry has been gaining momentum in the recent academic engagements. Despite its existence in many industries (i.e. publishing, retailing, financial and travel services) for over a decade, the construction industry is yet to catch up with them. This is due to several challenges whose existence are more dynamic and perhaps generic than static to various countries. The challenges are mostly defined, but their impacts are frequently varied with boundaries; and the same applied to drivers toward a successful BIM adoption. This study aims to establish barriers and drivers to adopting BIM across Nigerian construction industry professions for synchronization and collective engagements. Primary data was fetched from professional stakeholders (Architects, Engineers, Builders, Quantity Surveyors, Project Managers and Planners) using online structured questionnaire. A total of 68 valid responses were analyzed using descriptive statistics. The study reveals a significant improvement in awareness level with much better adoption rate; however, the utilization level remain very limited due to lack of clarity, knowledge and guide. Lack of expertise within organizations and within project team as well as lack of standardization and protocols (in descending order) were found as significant barriers to BIM adoption. On the other hand, availability of trained professionals to handle BIM tools, proof of cost savings by its adoption and the BIM software affordability (in descending order) were found as the significant drivers to achieving a quick and effective BIM adoption. Recommendations were made based on the study findings.

Keywords: *Adoption; Barriers; BIM; Construction; Drivers; Nigeria*

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Usage of Project Management Methods, Tools and Techniques in Infrastructure Projects

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We are witnesses of projectification of our world. Projects are evolving daily, in faster, bigger and more complex manner, requiring project management to adjust to these changes adequately. One of the major help project managers and their teams have in decision making, planning, monitoring, organizing and doing their everyday activities in general are set of different project management methods, tools and techniques. They are supposed to increase overall project success, which is often not the case, especially on projects of large infrastructure nature. The main aim of this article is to investigate which project management methods, tools and techniques, as well as project management methodologies and standards, managers of infrastructure projects use (due to their company and/or project requirements, knowledge or habits) in accordance to their perceived usefulness in context of Republic of Croatia. This kind of research may help in better targeting of those project management tools that really do make the difference in special contexts. This is especially important in world where added value to projects fulfilment is appreciated more than ever. Methodology used in this research was comprehensive literature review on the field, survey and statistical analysis. Results of the research may be useful both to project management scientists in directing their future research on the field, as well as project management practitioners and educators in usage and development of knowledge, skills and experience of working with the most effective methods, tools and techniques.

Keywords: *Infrastructure Projects; Methodology; Methods; Project Management; Techniques; Tools*

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Traceability for Built Assets: Proposed Framework for a Digital Record

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In May 2018, the UK Government published an independent review of building regulations and fire safety in response to the tragic fire at Grenfell Tower. The *Hackitt Review* identified the need for traceability; a 'golden thread' preserving critical information about design intent and the as-constructed building in a proposed Digital Record (DR). This study proposes a framework for a DR for traceability of all built assets, new and existing. Three structured workshops including four working groups were held with industry practitioners and academics to collaboratively establish definitions of traceability and a DR. The key requirements of the DR were identified through development of 63 use cases. Building on traceability systems research in other industries, a framework for traceability of built assets was developed and analysed with industry. The framework, containing both information chains, supply chains and unique identification of traceable items, is outlined in this paper and its key components are discussed along with identification of areas for further research.

Keywords: *Digital Record; Traceability; Information Chain, Supply Chain, Construction Industry; Hackitt Review*

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A Balanced Scorecard for Assessing Automation in Construction

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Despite the economic importance of the construction industry worldwide, it suffers from low productivity compared to other sectors, due to weak industrialisation, fragmented supply chain and poor collaboration. Recent national initiatives are promoting the adoption of information and automation technologies to increase efficiency, quality, safety, and reduce costs in construction. Emerging technologies will also provide highly integrated, connected and scalable new methods of construction. Nevertheless, the benefits and risks of automation in construction remain largely unknown due to the lack of standards and management tools to assess them from a holistic perspective.

The aim of this research is to develop a Balanced Scorecard (BSC) as an evaluation framework for automation in construction. A BSC is a strategic management system that links performance measurement to business strategy using a holistic set of performance assessment criteria. BSCs expand evaluation beyond financial criteria to include environmental and social considerations. The proposed BSC under development in this research uses a hierarchic system of multidimensional indicators (e.g. resource consumption, GHG emissions, costs, productivity, etc.) relevant to automation in construction, at operational, organisational and societal levels. The validity, priority and accessibility of the indicators were explored via a workshop with 20 participants from the construction industry. The workshop outcomes provided a means to focus attention on relevant key performance indicators (KPIs) for decision-making regarding construction processes. Based on the outcomes of this study, the final BSC will help construction organisations to achieve their sustainability goals and address low productivity, because automation solutions can be seen through a holistic, and pragmatic lens, thus are more likely to be included in, and contribute to, construction operations in the future.

Keywords: *Balanced Scorecard; Automation; Construction; Kpis; Sustainability, Assessment*

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Automation and Robotics in Construction:

Mirosław Jan Skibniewski

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Development Priorities and Key Challenges of Automation and Robotics in High-Rise Building Construction

Shiyao Cai[a], Zhiliang Ma[a], Mirosław Jan Skibniewski[b] and Song Bao[c]

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The construction industry is facing the challenges of low productivity, poor working environment, safety problems, an aging workforce. Particularly in high-rise building construction, these problems are serious because of the larger labor demand and a more dangerous working environment. Automation and robotics are expected to provide solutions to these problems while the level of application in the construction industry is still very low. This study identified development priorities (DPs) and key challenges (KCs) of automation and robotics in high-rise building construction through a questionnaire survey and an international expert workshop. Based on literature review and brainstorming, preliminary needs and influential factors were identified and a questionnaire was designed. The questionnaire survey was then conducted among senior engineers from major construction companies in China, evaluating the needs and influential factors related to robotics implementation. Based the results of the survey, an international workshop was held to furtherly identify DPs and KCs. This paper presents the processes and results of both the questionnaire survey and the workshop, identified and analyzed the DPs and KCs, and makes suggestions for future approaches to applying automation and robotics in high-rise building construction.

Keywords: *Automation and Robotics; Development Priority; High-Rise Building Construction; Key Challenge*

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Identification of the Interlayer Bond Between Repair Overlay and Concrete Using Nondestructive Testing, an Artificial Neural Network and Principal Component Analysis

Sławomir Czarnecki, **Łukasz Sadowski** and Jerzy Hoła

Wroclaw University of Science and Technology, Faculty of Civil Engineering, Wrocław, Poland

In construction practice, concrete elements are exposed to adverse environmental influences, and therefore sooner or later require repair. This repair is usually performed by removing the damaged concrete and replacing it with repair overlay. The quality of this repair is evaluated using the destructive pull-off method. In this method, the pull-off adhesion value between the repair overlay and repaired element is measured (f_b). Unfortunately, the disadvantage of this method is local damage of the element at every measuring point. It is therefore reasonable to present a reliable nondestructive method of identifying the interlayer pull-off adhesion value. The article presents the results of experimental research, which indicate that such identification is possible using complementary non-destructive methods and an artificial neural network with principal component analysis.

Keywords: *Concrete Interlayer Bond, Adhesion, Nondestructive Testing, Artificial Neural Network, Principal Component Analysis*

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Monitoring of Concrete Placement and Vibration for Real-Time Quality Control

Sang Gyu Lee and Mirosław Jan Skibniewski

Center of Excellence in Project Management, Department of Civil and Environmental Engineering, University of Maryland, College Park, MD, United States

This paper presents a conceptual framework for monitoring concrete placement and vibration operations. The proposed design is intended to enable collection and analysis of concrete pour data using computer vision and ultrasonic positioning. The system being developed alerts a project manager when workmanship observed is not in compliance with acceptable performance standards. The paper describes key operational factors in concrete placement and vibration that need to be monitored and reviews options for real-time locating systems. Fourteen factors related to concrete placement and their corresponding parameters are determined for measurement. In regard to the real-time locating systems, Ultra-wideband, ultrasonic, and computer vision technologies satisfy the expected levels of on-site positioning range and accuracy. Along with computer vision, ultrasonic technology has been chosen over Ultra-wideband alternative due to its lower cost and comparable performance.

Keywords: *Concrete Placement and Vibration; Quality Control; Real-Time Monitoring; Workmanship*

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29 June - 2 July 2019 | Budapest, Hungary

Fuzzy Logic and Neural Networks for Insulation Fault Diagnosis in Construction Robots Drives

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In building industry reliable uninterrupted power supply of construction robots drives is of particular importance, which is largely determined by reliable trouble-free operation of generating equipment. According to statistics, the majority of electricity in the world is produced by hydro and turbine generators, which are low-speed or high-speed synchronous machines. The urgent problem is the development of methods for non-destructive testing and insulation monitoring of synchronous machines. The main method of assessing the real technical condition is insulation control through the analysis of electrical discharge activity (EDA). This method allows detecting defects at an early stage of their development.

The actual problem is the development of automatic technical state diagnosis methods for insulation by the EDA parameter. The main parameters that are evaluated in the analysis of EDA is the shape and amplitude of the discharge phenomena.

The article proposes a method for determining the discharge phenomena form, based on a neural network classification model. It used two-layer network of direct signal transmission trained by Levenberg-Marquardt algorithm.

A method for determining the degree of defect development based on a neuro-fuzzy diagnostic model, differing by a joint analysis of the shape, amplitude and repetition rate of the pulses of a discharge phenomenon, which allow to determine the degree of defect development by relating it to one of the classes of diagnoses is proposed.

Keywords: *Construction Robots; Electrical Drives; Diagnostics of Isolation of a Synchronous Machines; Electric Discharge Activity; Fuzzy Logic; Neural Networks*

30 June 2019, 14:45-15:45

Sustainable Construction, Health Safety:

Wen-der Yu

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Safety Culture of the Herbert Hoover Dike Contractors

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The construction industry remains one of the most dangerous industries to work in even after decades of safety improvements. Researchers, such as Zohar, have argued that safety climate, or safety culture, is "a robust leading indicator or predictor of safety outcomes across industries and countries". This study made use of mixed methodology that blends quantitative and qualitative research methods to gauge the relative level of commitment each project's workforce has to a positive safety culture at Herbert Hoover Dike. The quantitative portion of the research revealed a positive perception of safety among craft workers. The qualitative portion of the research revealed major themes and subthemes associated with safety culture on the project. Further research is needed to capture additional workers on this project as well as connect safety culture with accident rate with this and other construction projects.

Keywords: *Herbert Hoover; Safety; Safety Culture*

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Forecasting Heating Degree Days for Energy Demand Modeling

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Heating degree day (HDD) is a technical index taking into consideration outdoor temperature and average room temperature to describe the need for the heating energy requirements of buildings. HDD can be used to normalize the energy consumption of buildings with respect to heating since the amount of energy needed to heat a building in a given frequency is directly related to the number of heating degree days in that particular frequency. In order to understand the heating demand of the buildings, it is important to investigate the HDD patterns and to construct forecasting models. This study aims at constructing short-term forecast models by analysing the patterns of the HDD. Within this context, time series analysis was conducted by the monthly HDD data in France between 1974 and 2017. The performance of the models were assessed by the adjusted R^2 value, residual sum of squares, the Akaike Information Criteria (AIC) and the Schwarz Information Criteria (SIC) as well as the analysis of the residuals. As a result, the most suitable model was determined as SARIMA $(2,0,1)(1,0,1)_{12}$. The results of the study show that there is a potential to integrate time series models of HDD for short term load forecasting.

Keywords: *Heating Degree Days; Short Term Forecasting; Time Series; Box-Jenkins Method; SARIMA Models*

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Clients and Construction Health and Safety (H&S)

John J. Smallwood

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Contractor H&S is influenced directly and indirectly by clients. Furthermore, traditionally, worldwide, better practice client organisations have maintained rigorous contractor H&S management programmes and contributed to contractor H&S.

Given the above, a self-administered questionnaire survey was conducted among developer members of the South African Property Owners Association's (SAPOA) to determine construction H&S perceptions and practices.

Findings include: clients view the traditional project parameters of time, quality, and cost as more important than public H&S and project H&S; client organisations can be deemed to have influenced and contributed to contractors' H&S relative to a range of interventions / requirements; clients appoint agents to fulfil their function in terms of the Construction Regulations; a range of design, procurement, and construction aspects impact on H&S; a range of benefits accrue from client contributions to contractor H&S; clients contend that they have influenced construction H&S, and that they could influence construction H&S more, and a range of design, procurement and construction aspects / interventions can contribute to an improvement in construction H&S.

Conclusions include that clients do influence construction H&S and that multi-stakeholder benefits accrue there from, and that clients can further contribute to construction H&S. Furthermore, the client related requirements of the Construction Regulations are underscored by the findings.

Recommendations include that property and other built environment tertiary education related programmes should address construction H&S, and SAPOA and other professional associations should evolve construction H&S practice notes.

Keywords: *Clients; Construction; Health and Safety*

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Assessment of Emerging Cooling Technologies by Analyzing their Impact on Reducing the Power Usage Effectiveness Ratio of Data Centers

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With the advent of high speed internet, smart-phones, Wi-Fi, Cloud computing, and IOT, our desire for creating and consuming data has been growing exponentially. It has resulted in great demand for storing and processing of this data with increase in number and scale of data center facilities around the globe. Data centers have started consuming much higher amount of power and high-performance IT equipment have presented a bigger challenge for cooling systems. Large technology companies have realized the need for making their data centers more energy efficient and, in turn, modern mechanical systems have been designed to work more efficiently. This research study endeavors to analyze these mechanical systems and present the way they affect Power Usage Effectiveness (PUE) ratios of data centers. Data from numerous data center projects carried out by a leading general contractor in last 5-years was obtained and correlation analysis was carried out to assess how modern mechanical systems help in reducing their PUE ratios.

Keywords: *Data; Effectiveness; Mechanical; Power; Usage*

30 June 2019, 16:30-17:45

Creative Management:
István Hajnal

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Impact of Bonding Capacity on Performance of Construction Contractors and Market

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Bonding capacity is an important element in the construction competitive bidding environment. Despite numerous works dedicated to studying different aspects of construction bidding, the impact of bonding capacity on the performance of contractors and market is not explored yet. Using agent-based modelling, this paper aims to examine how bonding capacity affects the financial performance of contractors and market. Agent-based modelling is a powerful modelling tool for simulating the actions and interactions of autonomous agents with the aim of analysing their effects on the system as a whole. The results of this paper show that the extreme limitation of bonding capacity can make the market less efficient. Also, increase in the number of rational contractors as result of a proper bonding capacity limitation restricts the chance of irrational contractors winning from higher uncertainty in cost estimating.

Keywords: *Construction Competitive Bidding; Bonding Capacity; Quantitative Bidding Methods; Simulation; Agent-Based Modeling*

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Conformance Evaluation of Lean Integrated Project Delivery (LIPD) for Indian Construction Industry

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Integrated project delivery (IPD) can be used to improve project outcomes using a collaborative approach through early involvement of parties and a multiparty agreement. Lean construction refers to the application & adaptation of the Toyota Production System (TPS) concepts and principles in construction projects for the reduction of waste. Over the last 20 years, the construction industry has become less efficient despite having good project delivery systems like Integrated Project Delivery (IPD), Design-Build (DB), Design-Bid-Build (DBB) and Construction Management Risk (CMR). The amount of waste (man, money, material & time) in different construction activities needs to be minimized to the maximum possible extent. An efficient project delivery system is missing for the Indian construction projects. This research work introduces Lean Integrated Project Delivery (LIPD) as a solution which uses a combination of lean management principles & IPD for waste reduction during construction activities. Further, LIPD conformance would be carried out in the Indian construction industry for the successful implementation of new project delivery system by identifying Critical Success Factors (CSF). Till date, there is no research carried showing LIPD conformance in India. Data for this research has been collected using questionnaire survey using Saaty's scale from experts working in several construction industries of India and has been analyzed using Analytical Hierarchy Process (AHP). The sample size for research work is 40, which was collected from 24 different construction & project management companies in India. This paper elaborates conformance of LIPD in India and the reason for poor implementation of the same.

Keywords: *AHP; IPD; Lean Construction; LIPD; Waste Reduction*

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Urban Consolidation Centre – In Context with Construction Consolidation Centre a Comparative Analysis

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Construction industry toiling with the adversarial relationship, competitive market, and low overall revenues continues to investigate, study and implement various frameworks that can enhance the relationship among the parties, standardize processes, and enhance productivity and profit margins. The paper takes into account the concept of lean manufacturing/production of waste minimization by the concept of UCC which dates back to 1970s, one of oldest and still functioning UCC is in Tenjin, Japan which was started in 1978. The study is done on UCC's at a different geographical location across the world trying to identify the factors that contribute to make it a success or failure. Based on the study-specific questions are prepared to analyse UCC's implementation in Asia's largest slum Dharavi situated in Mumbai the Financial Capital of India and will seek an answer to the question - can it help enhance the makeover of Dharavi

Keywords: *SHM; Building Construction; Technology; India; Construction Management; Building Material*

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Toward a Qualitative RFIs Content Analysis Approach to Improve Collaboration between Design and Construction Phases

Mathieu Fokwa Soh[a], Daniel Barbeau[b], Sylvie Dore[a] and Daniel Forgues[a]

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Requests for Information (RFIs) are formal processes, used in the industry of Architecture, Engineering and Construction (AEC), to obtain information not contained or inferable in the contract documents between the design and construction phases. RFIs produce rich, precise and structured sources of information. Analysis of RFIs content can help identify recurrent problems. The goal of this article is to present a method to identify problem areas during the construction phase of AEC projects through the analysis of RFI documents. Recent advances in the qualitative analysis of document content make this quest possible and fast. This article proposes to the scientific communities and AEC industry professionals, a systematic method based on the qualitative analysis of RFIs in order to propose some types of information to consider for a design more adapted to the construction phase. An example of the application in a steel construction project demonstrates the feasibility of this method and proposes some points to consider to improve the design of steel structures.

Keywords: *Construction Phase; Design Phase; Qualitative Content Analysis; Request for Information,*

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Barriers to Knowledge Management in Small and Medium Construction Companies in South Africa

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Small and medium enterprises (SMEs) within the construction industry have been described to be falling short in the adoption of several management practices that could help improve their service delivery and subsequent growth within the industry. Thus, this study set out to determine the various factors that could serve as barriers towards achieving proper knowledge management (KM) within these construction organisations. The study adopted a quantitative approach through the use of a questionnaire survey carried out among staff members and stakeholders in management positions of Grade 1 to 3 general building organisations within the Johannesburg region of South Africa. Data gathered were analysed using percentage and factor analysis. The reliability of the research instrument was also tested using Cronbach alpha test while the factorability of the data gathered was tested using the Kaiser-Meyer-Olkin measure of sampling adequacy and Bartlett's Test of Sphericity. The result revealed that the barriers to proper KM practices among SMEs in the study area can be categorised under the following: people related issues, SMEs organisational issues, and project demand issues. It is believed that the findings of this study will go a long way in assisting SME's owners in managing knowledge within their organisation by avoiding certain factors that could hinder effective KM.

Keywords: *Barriers; Knowledge Management; Organisation Management; Project Management; Small and Medium Companies*

30 June 2019, 16:30-17:45

Visualization, BIM:
Miklós Hajdu

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Development of an AR System for the Advancement of the Tasks in the Construction Sites

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In this paper, we developed an AR (Augmented Reality) application for productivity improvement in the construction sites. We developed this system for upgrading the ancient methods of construction by using the AR Technology. The main concept of this system is to use the AR technology for visualizing the completed form of the buildings, reforming the "construction management" and improving the productivity on the construction sites. This system can be used for the "presentation of the completed models" for early decision of the task to be performed, "safety work confirmation" for eliminating and reducing the dangerous tasks, "visualization of completed model before the completion of the buildings" for eradication of serious mistakes on quality of the buildings to be build. Generally, the AR system is used along with various types of head worn devices like Head mount displays or Google glass, but they are not realistic for the construction workers or in the construction sites. Our application works on iPad® and tablets which is easy to use and is a realistic form of using AR in the construction sites. Our application is developed in such a way that, the AR model generated from the BIM (Building Information Modeling), projected on 1:1 scale in a real space is continuously displayed in a smart device following the movement of the person holding the tablet. As a person moves holding the tablet, the position and orientation of the tablet is tracked, and the model follows the tablet. The developed system is experimented on the building construction sites in Japan. The experiments were conducted by developing the AR models from the BIM model of the various areas of the architectural construction sites. The experimental results reflect the effectivity of our AR system for increasing the productivity of the construction sites.

Keywords: *Architecture; Augmented Reality; Building Information Modeling (BIM); Construction*

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Linking Revit Facility Life-Cycle Data to ARCHIBUS – A Case Study of an Academic Institution

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Building owners and facility managers are beginning to leverage spatial information and asset data in BIMs for efficient and sustainable building operations and maintenance. Extracting information from BIMs for import into FM platforms still poses an implementation challenge to many owners. Methods for bi-directional synchronization of data between a BIM and FM software for real-time access to lifecycle model data can be more advantageous over one-way data export approaches so the owner can take advantage of an as-built BIM that can have data updated in real-time with continuous asset data updates. This paper uses a case study of a renovation project on a university campus to illustrate the use of the ARCHIBUS Smart Client for bidirectional real-time data exchange with Revit. The Archibus workflows were compared to other methods for data exchange as to how they support the needs of the owner. Lessons learned and challenges related to this workflow are discussed.

Keywords: *Building Information Modeling; Facility Management; Revit; Archibus; Asset Properties; Life Cycle Data*

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On-site Quality Assurance: Moving from Forms to Digital Capture

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The construction industry is in the midst of a transition with traditional design systems being replaced by novel 3D modelling technologies. This transition takes place gradually rather than radically, and while new systems (e.g. Building Information Modelling, BIM) become increasingly diffused in the industry, many legacy systems and practices are left intact. Quality assurance using the old method of filling out forms for the registration of errors and omissions is replaced by systems such as RIB Capture, where an app on a mobile phone is used to take a photo which is immediately sent to the person involved, e. g. carpenter, plumber, electrician etc. We ran a case study in a large industry standard type of residential project executed by a contractor. Data were collected based on a series of qualitative interviews conducted with the on-site personnel. This was analyzed according to the Technology Acceptance Model, which explains how individuals develop an intention to use new technology. Our contribution to the body of literature is that we compare the technology acceptance of new and existing quality assurance methods in order to unearth their relative advantages. This work is important for managers deciding on a combination of quality control tools, enabling them to better run their projects efficiently.

Keywords: *RIB Capture, Construction Management, Technology Acceptance Model, Quality Assurance*

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Assessing Workers' Perceived Risk During Construction Task Using a Wristband-Type Biosensor

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The construction industry has demonstrated a high frequency and severity of accidents. Construction accidents are the result of the interaction between unsafe work conditions and workers' unsafe behaviors. Given this relation, perceived risk is determined by an individual's response to a potential work hazard during the work. As such, risk perception is critical to understand workers' unsafe behaviors. Established methods of assessing workers' perceived risk have mainly relied on surveys and interviews. However, these post-hoc methods, which are limited to monitoring dynamic changes in risk perception and conducting surveys at a construction site, may prove cumbersome to workers. Additionally, these methods frequently suffer from self-reported bias. To overcome the limitations of previous subjective measures, this study aims to develop a framework for the objective and continuous prediction of construction workers' perceived risk using physiological signals [e.g., electrodermal activity (EDA)] acquired from workers' wristband-type biosensors. To achieve this objective, physiological signals were collected from eight construction workers while they performed regular tasks in the field. Various filtering methods were applied to exclude noises recorded in the signal and to extract various features of the signals as workers experienced different risk levels. Then, a supervised machine-learning model was trained to explore the applicability of the collected physiological signals for the prediction of risk perception. The results showed that features based on EDA data collected from wristbands are feasible and useful to the process of continuously monitoring workers' perceived risk during ongoing work. This study contributes to an in-depth understanding of construction workers' perceived risk by developing a noninvasive means of continuously monitoring workers' perceived risk.

Keywords: *Separated By Semicolons ;Construction Safety, Perceived Risk, Wearable Sensor, Electrodermal Activity, Supervised Learning*

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Feasibility Study of Integrating BIM and 3D Printing to Support Building Construction

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Although BIM has already been used to detect, simulate, and display construction details in many construction projects, these operations are performed and viewed exclusively on computers rather than on actual construction sites. In other words, when engineering staff holds meetings to discuss construction details, they are still required to use their imagination because they have no actual objects to refer to. Accordingly, they may be unable to correctly implement the construction details on actual sites, diminishing the benefits of BIM.

3D printing technology is becoming increasingly mature. In recent years, the construction industry has also frequently discussed the use of 3D printing technology. Scholars have indicated that combining BIM and 3D printing technology will be one of the future directions for expanding the use of BIM. Nevertheless, when examining the application of 3D printing, the construction industry has often focused on large-scale printing (e.g., printing the entire house). By contrast, this study, which integrated BIM and 3D printing technology, used a small version of the 3D printing model to review operations that were difficult to discuss through imagination (e.g., how to solve interface conflicts and assemble precast components). By using this 3D printing model, engineering staff could examine and assemble actual components at the construction sites, thereby facilitating the construction work. In short, by utilizing the BIM to produce 3D printing models and components, and using said models and components as the basis for construction site-related discussions, engineering staff may be able to elevate the overall construction results.

This study examined whether integrating BIM and 3D printing technology was a feasible option for helping building design and construction. Furthermore, this study investigated how BIM could be used to quickly generate 3D printing models and the effectiveness of using 3D printing technology to print actual components during the construction process.

Keywords: *3D Printing, Building Information Modeling, Construction Details*

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Sustainable Construction, Health and Safety: John J. Smallwood

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Analyzing BIM Interoperability for LCA Purposes

Mathieu Dupuis, Alain April and Daniel Forgues

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The use of building information modelling (BIM) is increasingly popular and results in the BIM model becoming the central data source in a construction project. The information available in BIM is hard to use because it lacks interoperability. This paper assesses every strategy to share data from BIM in order to support a life cycle assessment (LCA) for a whole building at every step of the BIM model design. Every open file format concerning the BIM is analyzed to determine if one file format can fulfill the data requirements of an LCA. Among all of these file formats, IFC is the best-known and most detailed format. An in-depth analysis of the IFC data schema and syntax is performed to determine whether the construction industry requires a specific file format for LCA purposes or whether one of the existing open file formats can be used as a data source.

Keywords: *BIM; Interoperability; LCA; Open Format File*

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An Overview of Real-time Occupancy Information Acquisition Method for Demand-driven Building Energy Management

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Efficient building energy management needs to meet both energy savings and user comfort requirements, which relies on the accurate acquisition of occupancy information over time. In order to meet the data requirements of different building application environments, this paper reviews different sensor technologies based on the principle of obtaining occupancy information, and divides them into five categories, namely motion sensors, environmental sensors, radio frequency (RF) sensors, camera, and contextual sensors. A review of the fusion of multiple sensors that have been widely used for building occupancy detection in recent years has also been conducted. The pros and cons of the prior art are discussed in detail, thus future research can better fit the needs of different system control (such as heating, ventilation, and air conditioning (HVAC) and lighting systems) in different types of buildings.

Keywords: *Building Energy Control; Occupancy Information; Sensor; Fusion*

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Energy Retrofitting of a Commercial Building Towards a ”Net Zero Energy Building” by Simulation Model

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Energy is one of the major drivers of a growing urban infrastructure development. The consumption of energy by different sectors of urban infrastructure are very high and the amount of energy produce is not enough to meet the huge demand of energy. According to several types of research, it is found that building sector is consuming about 40% of energy which is very significant. For heating and cooling of building sector 32% energy is used and its major impact is greenhouse gas emission. This study presents a simulation model that combines building properties and energy consumption of an existing commercial Building in Ahmedabad city (India). This research targets to study how to integrate active design strategies and energy-efficient building materials to improve the building performance and reduce energy consumption towards Net Zero Energy Building (NZEB). This research will suggest few changes in materials of building will be considered as retrofitting and it can lead to the concept of Net Zero Energy building (NZEB). For the analysis and simulation of energy, Design- Builder software is used.

Keywords: *Energy Retrofit; Net Zero Energy Buildings (NZEB); Commercial Building; Building Envelope; Simulation*

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Social Identity, Safety Climate and Safety Behavior Among Mine Construction Workers

Yuzhong Shen[a], Jiawen Han[a], Jiemin Zhang[a], Zengzhong Wang[a], Xinghai Chen[a], Zhizhou Xu[a], Jingjing Kong[a], Xingxiang Zhao[a], Steve Rowlinson[b]

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Creating a sound safety climate is accepted as an effective measure to curb unsafe behavior, which is the primary cause of construction accidents. However, the issue is open to debate as to which factors contribute to a sound safety climate. Using questionnaire responses from mine construction workers, this paper examines the impact of social identity on safety climate and hence safety behavior based on the structural equation modeling technique. Results show that workers who identify themselves primarily with their crews have stronger safety climate perceptions, while those workers who have stronger identification with the construction project have weaker safety climate perceptions. Surprisingly, group safety climate fail to mediate the relationship between workers' group identity and their safety behavior. The results highlight the role of crew leaders in creating a sound safety climate and curbing unsafe behavior.

Keywords: *Mine Construction Workers; Safety Behavior; Safety Climate; Social Identity; Structural Equation Modeling*

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Assessment of the Use of Delphi Technique in Sustainable Infrastructure Development Research

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The Delphi technique over the recent decades has increasingly become generally recognized and accepted by a vast range of institutions, government departments, and policy research organizations across the globe. The Delphi method was originally developed in the 50s by the RAND Corporation (an American non-profit global policy think tank aimed at offering research and analysis to the United States Armed Forces) after a series of studies and observations in Santa Monica, California. This approach encompasses a survey conducted in two or more rounds and affords the participants in the second round with the results of the first so that they can modify the original assessments if they want to or stick to their former opinion. It is usually presumed that the method makes better use of group interaction whereby the questionnaire is used as the medium of interaction. The Delphi method is especially useful for long-range forecasting; as expert opinions are the only source of information available. The objective of this paper is to outline how the Delphi technique process was used to predict and understand issues surrounding sustainable infrastructure development in developing countries. The paper's objective is based on the premise that the technique has not been widely used to study sustainable infrastructure development, despite several empirical studies that have been conducted in its favour. This is because the Delphi approach solicits experts' views on subjects surrounded with confusion. The methodological approach adopted for the study was a content analysis of published peer reviewed journal articles with regard to the use of the technique in Sustainable Infrastructure Development studies. The Delphi technique is discussed because it is an accepted and reliable research technique that helps to resolve experts' disagreement with issues.

Keywords: *Assessment; Delphi Technique; Developing Countries; Research; Sustainable Infrastructure*

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1 July 2019, 9:15-10:15

Creative Management:
Keith Rahn

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Emergent Subcontracting Models and Owner Involvement in Selecting Subcontracting Strategies and Participants in the U.S. Construction Industry

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Prime contracting models for a wide variety of Project Delivery Methods (PDM) have been described with great detail in the practice-oriented and academic literature. However, the same depth of understanding about contractual relationships between general and specialty contractors is less known, especially as specialty contractors are being increasingly involved in earlier project phases. The objective of this research is to describe subcontracting models, owner involvement scenarios, and their variations across the United States. Results of a nationwide survey and follow-up semi-structured interviews with industry practitioners indicate many subcontracting models are currently in use and that project owner involvement is widely variable. Presentation attendees should expect to gain a greater understanding of each of the identified subcontracting models as well as to learn the advantages, disadvantages, regional variations, and owner involvement under each.

Keywords: *Subcontracting Model; Nationwide; Variations*

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Input for Hybrid Simulation Modelling Construction Operations

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Good pre-construction planning efforts are a vital part of the effective management and delivery of construction projects. In order to prepare more accurate schedules and cost calculations, realistic productivity rates to improve precision are needed. The use of simulation for modelling the elements of construction processes can assist with this aspiration. The application of hybrid simulation approaches is particularly appropriate as they can capture complicated behaviour, uncertainties, and dependencies. This paper discusses the use of one such approach combining discrete-event simulation (DES) and system dynamics (SD) to determine more accurate productivity rates. The DES component models the operations with the workflow of the tasks performed. Its input consists of the task elements with their durations and resource information. The factors that influence the productivity rates are taken into account with the help of the SD component. Input for this part of the model includes the factors as well as considerations of their interrelationships and effects. In this work, a case study of such input data for masonry works – for brick- and blockwork – is presented. It shows the input data and its integration in the DES-SD approach for modellers to determine more realistic productivity rates.

Keywords: *Discrete-Event Simulation; Labour; Masonry; Modelling; Productivity; Simulation; System Dynamics*

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Towards a Parsimonious Information Management for Energy Retrofitting of Buildings

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[b] *Tsinghua University, Beijing, China*

Throughout the world there are thousands of residential and public buildings that have been built during the reconstruction and rapid urbanization after the 2nd world war, particularly Eastern and Central Europe as well as in China. These are the most efficient target for mass improvement of their energy use through the improvements of façade insulation and windows. Advanced information technology (IT) - including building information modelling technology (BIM) - is not used very often in these renovations. Our hypothesis is that the use of BIM could be more efficient if it would focus on the essential information needs of the actors involved. The key idea of BIM - structured collaborative shared database of all required information - should be preserved but the model should be parsimonious. The paper presents the ongoing research in the context of a bilateral Chinese-Slovenian project with the goal of designing parsimonious information management for the retrofitting of existing buildings. The broader goal of the work is to study information modelling supporting works where a complete information model may not be needed at all and where a detail process definition - as outlined in BIM execution plan and related documents - would lead to overspecification, constraining the workflow.

Keywords: *Building Information Modeling; Energy Efficiency; Renovation; Building Process; Parsimonious*

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Industrialized and Project-based Construction - Standards Versus Business Models

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Digitalization transforms the design, construction and operation of buildings and brings promises of integrated information exchange, ease of communication and productivity improvements for the whole construction sector. These promises depend significantly on the establishment of common information standards, i.e. rules and classification of information. However, despite rigorous efforts on development of standards and considerable technology advancements, standards are not yet fully adopted in construction and benefits from digitalization are not fully capitalized. The objective of this study is to review the adoption of standards and business model renewal for industrialized suppliers of precast concrete elements, with the purpose of reaching enhanced understanding of the mechanisms of standards adoption and business model renewal. The study identifies driving forces for adoption of standards that counteract with arguments for business renewal, explained in terms of a market versus a hierarchy approach in this context. The market approach promotes adoption of open standards for enhanced competition, ease of communication and information exchange as well as improved utilization of industrialized construction. The existing lack of common standards for precast elements, identified in this study, render e.g. waste due to structural re-design and liability uncertainties. However, on a market with open standards, the precast suppliers find it difficult to fully utilize and benefit from their existing operational platforms. Precast supplier search for adoption of the whole value chain of precast structural frameworks, i.e. a hierarchy approach, to protect their market position and maintain their business offerings of complete structural frameworks that include design, manufacturing, logistical services as well as on-site assembly. The integrated hierarchy approach concurs with arguments for industrialized construction, i.e. collecting experiences from design, manufacturing, logistics and assembly as a basis for continuous improvements. The study thus contributes to the understanding of drivers and impediments for adoption of standards versus business renewal in construction.

Keywords: *Industrialized Construction, Information Standards; Business Model; Precast Element; Product Service System*

1 July 2019, 9:15-10:15

Visualization, BIM:
Miklós Hajdu

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A Synopsis of 3D Printing and Robotics Applications in Construction

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One of the difficulties hindering the application of 3D printing technology in construction is related to the versatility of materials and components used to produce a building or other structure. The prospect of using this technology is further complicated by the sheer size of the edifices to be constructed. While 3D printing a mechanical component can now be done in someone's basement with affordable and readily available equipment, applying the same technology to produce large structures and building components is a challenge. In recent years, researchers have been working towards overcoming this challenge by trying to develop new construction materials and methods that would be more suitable for the application of 3D printing technology. One of the approaches that can be considered is the combination of robotics technology with 3D printing to automate construction activities. The use of robots in construction has been proposed long before 3D printing became possible or known but never gained widespread construction site usage, mainly because of the difficulty associated with the automation of most construction tasks. However, the combination of 3D printing with robotics may be the way to change that. In this paper, the authors examine the suitability of 3D printing in a number of construction tasks and present ideas that modify established construction methods to make them more suitable for automation. The authors then examine how the introduction of robotics in conjunction with 3D printing to the construction site may make it possible to automate a number of construction tasks. Some of the benefits of such automation include lower safety risks, improved control over construction schedules, more economical construction, and a better ability to build in remote areas and challenging environments.

Keywords: *3d Printing, Construction Automation, Construction Technology, Robotics;*

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3D Printing Applications in Construction from the Past and into the Future

M. Ammar Alzarrad and **Souhail Elhouar**

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The advent of 3D printing technology may very well be remembered as one of the most important technological advances of the early twenty-first century. This technology is transforming the dynamics of the manufacturing world in ways that may have not been thought possible a couple of decades ago. 3D printing is now being used in medicine and dentistry to make prosthetic parts, sensors, and medical models among a number of other applications. The versatility of the types of materials that can be 3D printed makes the process extremely useful. The technology is being used in different industries to produce various parts and components for generally lower costs while achieving a better quality. This is either achieved by 3D printing the parts themselves or the molds that would eventually be used to make the parts. However, the construction industry has been slow in adopting this technology for many reasons, many of which still need to be investigated so a way can be found around them. In this paper the authors first examine the history of 3D printing applications in the construction industry. They then provide an overview of recent attempts at applying the technology while discussing the successes and challenges encountered. They finally propose solutions for resolving some of the identified challenges to help the industry move forward in taking advantage of this emerging and potentially beneficial technology.

Keywords: *3D Printing, Construction Automation, Construction Technology*

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Building Information Models' Data for Machine Learning Systems in Construction Management

Dimosthenis Kifokeris, Mattias Roupé, Mikael Johansson and Christian Koch

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Qualitative and quantitative data are important in construction management. However, despite the capabilities of construction informatics, such data and its sources have scarcely been fully and systematically utilized for predictive purposes. Building Information Models (BIM) are such a data source. Within BIM, information structures enabling interoperability and providing utilizable data throughout the various Levels of Development (LODs) of a building – for example, Industry Foundation Classes (IFCs) – can be fully and meaningfully exploited through data mining, and more particularly, via machine learning. In this paper, the capabilities of the information structures found in IFCs to be used as data sources for developing machine learning predictive models, will be examined. In addition, and by conceptually tying such data with constructability, their suitability for predicting – through such machine learning models – the delivery cost and time overheads of a construction project, will be considered.

Keywords: *Building Information Models; Construction Informatics; Data Mining; Industry Foundation Classes; Machine Learning*

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Discovering the Level of BIM Implementation at South African Architecture Schools: A Qualitative Study

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It is a well-known fact the architecture industry is at the forefront of implementing and using Building Information Modelling (BIM) to conceptualize, develop, resolve and execute buildings. Although it may seem like a new concept, BIM had its foundations set in the 1980's with the disruption being 3D CAD. BIM has significantly been revolutionized beyond the likes of 3D CAD to become a complex system of information. Currently, BIM is still revolutionizing how architects design buildings by intelligently documenting buildings, realistic visualization, error reduction and 3D resolution of construction detailing. However, when and where is BIM implemented to allow architects to maneuver in the complex web of BIM? In recent times, BIM has become a household phrase amongst architecture schools around the world. BIM is fundamentally important in the architectural design and construction courses as it allows students to explore their designs and resolve problems surrounding the resolution of designs, construction of buildings. materiality etc. BIM is a complex system of information and is an ever-changing philosophy that has changed how buildings are conceptualized and executed. As BIM revolutionizes the architecture industry, it is important to grasp the level of implementation and methods of executing the teaching pedagogies in teaching BIM. From various research conducted, it is evident that the architecture industry is at the forefront of BIM implementation, however is this the case at the various schools of architecture? This research focuses on the levels of implementation of BIM at schools of architecture in South Africa. The research makes use of a mixed method approach of both primary and secondary data. The primary method of data collection was executed using a qualitative interview-based approach to unravel the various opportunities and challenges faced at architecture schools in teaching and disseminating BIM knowledge in South Africa. The interview schedule was based on various questions including the current state of implementation, equipment, lecturer's knowledge and importance of an integrated BIM philosophy in courses. The secondary data for this research was collected through an intense literature review that sought to discover the implementation of BIM throughout the world and the opportunities and challenges experienced by other international schools of architecture. Preliminary findings reveal that there is some usage of 2D, and 3D CAD being implemented, however little implementation of BIM methods, processes and pedagogies have been recorded, which prompted the need for research in this key area. This research will be useful to Universities which are currently implementing BIM, the BIM research community, Industry and other stakeholders which wish to contribute to the body of knowledge of Building Information Modelling.

Keywords: *BIM; Architecture Schools; Pedagogy; South Africa; Industry 4.0*

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Creative Construction Technology and Materials: Levente Mályusz

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Assessment of the Failure Process of Self-compacting Concrete Modified with SiO_2 Nanoparticles by Acoustic Emission Method

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One of the new directions in self-compacting concrete (SCC) research is the modification of its composition with the addition of nanoparticles, which due to their unique properties are believed to improve the mechanical properties of cementitious composites. An important issue concerning the mechanical behavior of concrete under compression load is the failure process. At the moment, however, there is no knowledge of the effect of nanoparticles on the failure process of compressed SCC. The aim of the work is to investigate the failure process of compressed self-compacting concrete based on coarse and fine granite aggregate made both without and with SiO_2 nanoparticles in the amount of 2.0% and 4.0% of the cement weight. The research includes the determination of the levels of the initial cracking stresses σ_i and the critical stresses σ_{cr} that delimit individual stages of the studied process. Investigations were carried out using the acoustic emission (AE) method, and during the tests the recorded descriptors were the sum of counts (N_c) and the average effective value of the acoustic emission signal (RMS). The paper shows that the addition of SiO_2 nanoparticles has a positive effect on the failure process of compressed SCC. Moreover, the practical aspect of the obtained results for engineering purposes is provided.

Keywords: *Acoustic Emission; Failure Process; Initiate Cracking And Critical Stresses; Nanoparticles; Self-Compacting Concrete*

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Radiant Wall Cooling for Sheltered Structures in Underdeveloped Countries in Extreme Climates

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Hot and harsh climates of many underdeveloped countries are extremely problematic. People find themselves battling heat exhaustion and premature death caused by unforgiving heat events. The aim of this research is to improve the thermal comfort of Haitian residential shelters through testing radiant wall cooling and sustainable design principles. The research is limited to concentrate on small sheltered structures typically found in locations of low-income families, specifically in Haiti. The researchers focused on through literature review by investigating (1) previous case studies, (2) industry standards means and methods of sustainable construction, and (3) current trends in the host nation residential construction, striving for the most plausible acceptance of residential hybrid technology. The study includes the assemblies of a composite design--i.e., corrugated metal, bamboo and water delivery--to function and achieve a betterment for an interior shelter climate, by constructing a small replica test model. The limited scale model was constructed and tested in an effort to prove or disprove the theory of thermal comfort utilizing radiant wall cooling in hot climates. The model used both host nation common materials, and limited outside technology; thus enabling ease of accessibility to the native people. The testing of the models occurred in three phases; two of which are presented in this paper. The use of Fluke thermal imaging and Fluke temperature and moisture instrumentation were utilized collect data from the models. The findings of this study conclude the integration of such material assemblies are appropriate to change the performance of the interior shelter space during hot climates. It is with these efforts and findings the researchers are encouraged and look to open dialogue among architectural, engineering and building professionals to create new levels of thinking into more exploratory means per each individual host nation's challenges. These hybrid methods of construction may quickly be implemented and continued long after humanitarian efforts have departed.

Keywords: *Bamboo: Haiti; Radiant Cooling; Sustainable; Thermal Comfort*

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The Delunay Triangulation in the Design of Architectural Gridshells

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The design of original gridshell forms has become an increasingly complex process, which aims to search for unique spatial systems which are also effective engineering solutions – both architecturally as well as structurally. The search for synergistic solutions which combine the aesthetics of the form with structural logic is supported by modern bionic tendencies. They allow the reproduction of the organic shapes not only by means of proportions, but also by mimicking the biological developmental processes and by understanding the logic of the structural forms occurring in nature. The analogies between architectural design and morphogenesis of biological forms have increased the interest in bionic structures as a whole. The improvement of digital tools based on algorithmic codes has enabled architects to implement their bold designs based on the logic of Nature's technologies.

One of the most interesting bionic methods of discretization of structural surfaces is Delaunay triangulation, a dual graph of the Voronoi Diagram, which describes the divisions of the plane and space found in nature. Examples can be found in the patterns of a dragonfly wing, giraffe's mottled skin or a turtle's shell. The Delaunay divisions are more and more often used in the design of architectural forms based on gridshells. Solutions for such systems are obtained through generative modeling, and the algorithm responsible for the surface discretization is incorporated into 3D modeling programs. A big advantage of using digital generators in the search for optimal architectural and structural solutions is the ability to model multiple-variants and to the easily modify them (the models result from iterations of the entered numerical data).

The paper will present the trends in the development of spatial bionic gridshells based on Delaunay triangulation, as well as the results from own research on selected gridshells. The undertaken analyses compare material efficiency on two analyzed cases.

Keywords: *Surface Discretization, Generative Modeling, Delunay*

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A Review of Studies in Structural Health Monitoring (SHM)

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India is a country of diversity not only in terms of culture and population but also in terms of landscape ranging from snow-capped mountains to desserts, plateaus, plains and hills. The climatic conditions in India vary from extremely hot to extremely cold resulting in the requirement of different types of constructions in each region subjected to its temperature, geographical and climate conditions. India is a county where thousands of years old buildings are still standing strong despite several changes in various factors over the years, whereas a few years old building collapses more easily, which raises the most important question in our mind regarding the Structural health of buildings over the years and how Well structure health monitoring is done in India. Structural Health Monitoring is defined as a process of identification of damage for aerospace, mechanical and civil infrastructure. Performance of the structures are determined by various factors such as the age of the building, material used, service condition and layout of the structure besides performance, safety, reliability and serviceability are also the crucial points. SHM technology is implemented in various countries like Europe, USA, Korea, Japan etc. for monitoring of large structures. The main aim behind the implementation of SHM is to determine the damage during initiation itself so that the further damage propagation can be ceased by an alarm in the initial stage with the help of continuous monitoring by structurally integrated sensors.

Keywords: *SHM; Building Construction; Technology; India; Construction Management; Building Material*

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Creative Management:
Žiga Turk

CCC2019 CREATIVE CONSTRUCTION CONFERENCE
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Probabilistic Risk Appraisal and Mitigation of Critical Infrastructures for Seismic Extreme Events

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The importance and the interdependencies of critical infrastructures such as power and water supply, communications, and healthcare is increasing continuously and constantly. Most of the vital services for the private and the public sectors depend on the continuous performance of critical infrastructures. However, the last decades' extreme events reveal a significant gap between the preparedness of critical infrastructures and the actual risk that those infrastructures are exposed to in case of seismic event. In this research a methodology is developed to appraise and mitigate the risk that critical infrastructures are exposed to in case of seismic events. The proposed method is designated also to act as decision support tool for the selection of the most advantageous strategy to reduce the risk expectancy for extreme seismic events. A Probabilistic Seismic Hazard Analysis (PSHA) approach is used in order to reflect a variety of possible seismic scenarios and overcome the uncertainties regarding to the timing, the location, and the magnitude of an earthquake. The seismic vulnerability of different components is evaluated by adjusted fragility curves and Fault-Tree-Analysis. The seismic risk function, that expresses the expected risk of the system for a given ground motion intensity, is derived according to the occurrence probabilities of the earthquake, the seismic vulnerability of different components, and the expected consequences. This paper introduces the developed methodology and demonstrates the key steps through two case studies of oil pumping plant and oil tank farm. The pumping plant case study demonstrates the development of the risk function and examines the contribution of a possible mitigation strategy on the overall risk expectancy. The oil tank farm case demonstrates a derivation of an exclusive fragility function for critical infrastructures facility. This methodology provides a novel analytical and decision-support tool that integrates between the components adjusted fragility curves in the risk assessment and the consequent mitigation step; the optimal mitigation strategy is derived from the fragility parameters reflection on the total risk function.

Keywords: *Critical Infrastructure; Risk Appraisal; Risk Mitigation; Fragility Curves; Earthquakes*

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Effectiveness of Drone-Based Photogrammetry for On-site Quantity Assessment

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Drone-based surveying using laser scanning with LIDAR has been routinely used in heavy construction to produce high-quality topographical data with increased grid/mesh density when compared to traditional surveying. Differences between pre-construction conditions and post-construction topographical scans thus provides a basis for identifying the work performed, measuring progress and managing progress payments. The technique has demonstrated cost-effectiveness with less physical effort and less time becoming the go-to technology on large unit-price heavy construction projects. The approach is not routinely used on smaller projects partially due to the cost of acquiring the technology or outsourced services. Alternative technologies are desired which could benefit smaller and potentially more diverse construction activities. One promising approach involves using reality capture based on high-resolution imagery. This approach processes a cloud of geolocated imagery to develop virtual models which can then be integrated and analyzed through a BIM platform. Drones-based imagery through off-the shelf unmanned autonomous vehicles (UAV's) provide the ideal input for this reality capture techniques. The reliability of the resulting models is unknown, however, and research was performed to identify the reliability of the technique to determine on-site volumetric and area quantities. Various off-the-shelf UAV's (drones) were evaluated and statistical techniques were employed to quantify the reliability of the resulting models. Regression was used to extract data obtained through systematic trials to site-level applications. Results are presented and future directions are outlined and discussed.

Keywords: *Construction, UAV, Drones, Estimating, Quantity Surveying*

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Current Supply Chain Management in Construction Industry

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Supply Chain Management (SCM) in construction industry is a developing field of study. This paper analyses the results of a questionnaire survey on supply chain management in top US construction industries. A survey was sent out via online tool to more than 100 contracting companies in the US, mapping the relationship between contractors and suppliers, the tools and methods employed in executing the supply chain practices. The survey results indicated that SCM in the construction industry is still in its developing state. They also indicated that the construction industry has been relatively slow in adopting SCM as a tactic due to its complexity and uniqueness. The study recommends several solutions to overcome the above mentioned problems and improve the efficiency of the SCM in the construction industry.

Keywords: *Construction Industry, Supply chain, Construction Supply Chain Management, ANOVA*

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Implementing Progressive Design Build, A Case Study: UW West Campus Utility Plant

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Design-Build (DB) contracts have been used for many years in the United States of America. The award of a DB contract frequently relies on evaluating which DB team provides for the best value through a multi-criteria evaluation process with price being one of the most important criteria for team selection. To ensure project success, the owner usually has to spend adequate efforts and time during scoping and early design to prepare a program, scope, and budget, which are defined enough to undergo procurement and price generation. This, however, has become a potential burden for the owner, and may lengthen the project development duration. As an alternative to traditional Design-Build, Progressive Design-Build (PDB) provides for the selection of the DB team prior to deciding the program and/or budget for the project. PDB has the advantage of maintaining a single point of accountability and allowing to select a team based mainly on their qualifications with a limited price consideration. Under PDB, the selected team will work with the agency's stakeholders during the early design while helping the owner to balance scope and budget. The key to understanding PDB, however, lies in the ongoing and complete involvement of the owner in the early design phase. Due to the differences between PDB and the other project delivery methods (e.g., traditional DB), several factors must be considered carefully to assure the successful implementation of PDB. However, information on PDB is lacking because of its novelty. This paper aims to investigate the implementation of PDB by conducting a case study of the University of Washington's pilot PDB project for completing the West Campus Utility Plant (WCUP). The project's entire delivery process and organizational structures are summarized and presented.

Keywords: *Progressive Design Build; Project Delivery Method*

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The Impact of Construction Dispute on Projects in the Mpumalanga Province of South Africa

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Construction disputes have a greater effects on the construction industry as opposed to other industries. Especially negative effects are prevalent on the project participants which lead to poor execution of the project. The study investigated the impact of disputes in construction projects in the Mpumalanga Province. The data used in this paper were derived from both primary and secondary sources. The secondary data was collected via a detailed review of related literature. The primary data was collected through a survey questionnaire which was distributed to project participants. Out of the 90 questionnaires sent out, 80 were received back representing 89% response rate. Data received from the questionnaires were analysed using descriptive statistics procedures such as Ms Excel and SPSS software. Findings from the study revealed that; bad relationship between parties, loss of productivity, cost and time overruns, loss of company reputation, loss of professional reputation delayed payment and rework were the main effects of construction disputes in construction projects. Therefore, construction dispute have an effect on most of the project participants which may lead to poor execution, reduced profit margins and budget escalation. Hence Dispute must be resolved as soon as possible to avoid mostly all the effect they have on projects and stakeholders. Furthermore, risk have been identified to be associated with construction dispute, if risk are well managed the occurrence of construction dispute will be reduced.

Keywords: *Construction Industry; Construction Projects; Impact; Mpumalanga Province*

1 July 2019, 10:45-12:00

Visualization, BIM:
Orsolya Bokor

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Simulating Interaction Dynamics of Refurbishment Project Stakeholders through Agent-based Modeling Towards Enhancing BIM Adoption Effectiveness

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Building Information Modelling (BIM) is an IT enabled technology that supports information sharing, access, update of data and use, and allows storage of information and management. While the technology itself is not new, similar approaches have been in use for the construction of new builds, but the refurbishment domain is yet to catch up with the ability to exploit BIM benefits. The study offers an avenue to investigate the effectiveness of adopting BIM for complex refurbishment projects through a simulation of the interaction of refurbishment project stakeholders network using agent-based modelling performed through a parameterized Bayesian network. Previous investigations show that stakeholders hold the common ground to make effective decision towards adoption of BIM for complex refurbishment project. The aim of this paper is to present the results of current simulations made using Hepar II network on the interaction of project stakeholders for refurbishment project case study of a tertiary institution in New Zealand. In addition, the paper investigates whether there are benefits towards adoption of BIM considering the influences of the modification of the threshold error parameter on the final factor observation states.

Keywords: *Building Information Modelling (BIM); Refurbishment Project Stakeholders; Interaction Networks; Agent-Based Simulation*

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Building Information Modeling (BIM) for Safety Risk Identification in Construction Projects

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A significant number of fatal accidents and injuries are still reported in construction projects worldwide inducing consequent socioeconomic impacts. A crucial factor in construction safety is to properly identify possible hazards at any stage of the construction process. Existing research has not focused much on the automatic detection of risks associated with the inexistence or misplacement of protective safety equipment. This paper presents a method for detecting safety risks (to which workers may be exposed in a construction project) concerning the inappropriate placement or handling of protective equipment. In this approach, the construction site is dynamically modeled employing Building Information Modeling (BIM) technology. In particular, the project status is recorded at regular intervals using a camera. The data provided by the camera are transferred to BIM software and the site plan view is processed via a Matlab pattern recognition module to observe protective equipment misplacement or removal. The software compares the current image with the anticipated safety protection plan of the construction work and automatically detects the safety potential hazards areas along the work area. Within the extracting results, visual representation and labeling of the work areas that present unsafe conditions for the workers are developed and prompt alerts are forwarded to the project supervisor by e-mail specifying the location and type of hazard. The employment of the presented methodology could enable participants in the construction process to promptly identify and restore safety deficiencies, improving thus work safety and minimizing the number and/or the impact of accidents in construction sites.

Keywords: *Building Information Modeling (BIM); Work Safety; Risk Identification; Pattern Recognition; Job Hazard Areas*

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Using Augmented Reality for Masonry and Concrete Embed Coordination

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Missing or misaligned embeds, sleeves and penetrations for concrete and masonry construction have historically caused disruptions and errors in commercial construction resulting in delays, rework and cost overruns. In order to locate embeds, sleeves and penetrations through the traditional process requires a special set of coordination drawings to be produced called “lift drawings.” The “lift drawings” are essentially elevation views of critical wall and foundations elements which show the exact location and alignment for the embeds or penetrations. Producing these “lift drawings” is a time consuming and tedious process that is typically undertaken by the construction management professionals in order to assure that these elements are located properly within the building.

In the age of BIM this process of producing “lift drawings” for embeds, sleeves and penetrations should be coordinated and streamlined using BIM and augmented reality to reduce the work effort and provide greater efficiencies. This paper seeks to discover ways in which BIM combined with augmented reality and traditional surveying hardware can improve the process of embed, sleeve and penetration coordination.

Keywords: *Augmented Reality, BIM, Coordination, Surveying*

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Micro BIM Adoption: Identifying Cause and Effect Factors and Analysing their Inter-dependencies Using a Fuzzy DEMATEL Approach

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Several factors affect the process of BIM adoption within organisations (i.e. micro BIM adoption). An extensive collection of such factors were included in a unified BIM adoption taxonomy published in Ahmed and Kassem (2018). These factors are distributed across three areas of adoption drivers: the characteristics of the innovation itself (i.e., BIM), the external environment, and the internal environment of the adopting organisation. BIM adoption is a multi-staged process that entails varying interactions between factors from across the three driver areas and the stages of the BIM adoption process. Hence, this study argues for an improved understanding of the adoption topic beyond the current level offered by common approaches such as ranking factors affecting adoption (conceived as a single decision/milestone) and analysing correlations. In particular, there is a need to analyse the complex inter-dependencies between factors affecting the adoption process and its individual stages (i.e., awareness, intention, decision, etc.). This paper aims to understand these inter-dependencies by considering the micro BIM adoption as a complex system. The paper investigates the relative levels of influence between the factors affecting the system and classifies such factors in cause and effect factors at different stages of the adoption process. To achieve this objective, the research employs the Fuzzy Decision Making Trial and Evaluation Laboratory (F-DEMATEL) method. The application of the F-DEMATEL considered the top 11 factors (as identified in Ahmed and Kassem, 2018) that affect BIM adoption within the UK Architecture sector. The F-DEMATEL was applied for the entire adoption process as a 'single' system (i.e. without separating it into multiple stages) and for each individual stage (i.e. awareness, intention, and decision). The results from the F-DEMATEL (i.e., classification of factors into cause and effect groups and into four quadrants, and their inter-relationships) provided a new understanding of the BIM adoptions process. These results can be used to tailor and prioritise BIM implementation actions and investments when develop micro BIM adoption strategies.

Keywords: *BIM; BIM Adoption Process; Micro BIM Adoption; F-DEMATEL; Adoption Factors*

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Using UAV's and BIM Integration to Improve Infrastructure Delivery – A Case of Gauteng Department of Infrastructure Development, South Africa

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Meeting planned timelines, quality and budget requirements in construction projects is always a challenge and the impact means that resources that should be used in other development projects get re-directed to addressing the problems created by exceeding time, quality and cost aberrations. However, the fourth industrial revolution has not spared the construction industry and it is affecting the way infrastructure is delivered. According to the World Economic Forum, digital technologies have begun to change how infrastructure and the built assets are designed, constructed, operated and maintained. The entry of technology to the industry is also driven by the realization that in order to improve on the delivery of projects, adoption of innovative methods that are based on digital technology is essential as it ensures efficiency and effectiveness in project management, transparency, and record keeping. In this study, we report on the use of drones (Unmanned Aerial Vehicles - UAV) to capture site data and how it was integrated to Building Information Modelling (BIM) models to produce as-built drawings and quality checks from comparisons with as-imagined models. Data used in the study was obtained from construction projects sponsored by the Gauteng department of infrastructure, in South Africa. Findings demonstrate that UAV and BIM technology has the potential to improve the efficiency and effectiveness of project delivery. An enhancement in monitoring of work progress during construction, site surveillance, and integration of transformed 3D models to BIM to achieve more effective project management, record keeping, and quality control were observed. The accuracy of the data was also found to be adequate for the purpose of project management tasks.

Keywords: *BIM; CPM; Drones, Integration Management; South Africa; UAV*

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Creative Construction Technology and Materials: István Hajnal

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Creative Construction and Simplicity of Form

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An Architect designing a form has to take many factors into account. Some are mainly pragmatic and rational in nature. They correspond with the needs and restrictions determined by the user, site or function to name a few. Other factors are subjective to the designer, his/her talent and creativity.

One of many tendencies in contemporary architecture is designing buildings that look surprising and innovative. Their complex geometries are usually showing the prestige and the use of modern techniques and technologies.

In architecture the relationship between pragmatism, creativity, prestige and astonishment can be seen in buildings which are simple and solid blocks. The feeling of surprise is hidden in the internal structure. The outer form is designed in a pragmatic way while the interior form is different and stunning to the observer. This structure may serve a functional purpose, but the way it is composed into the whole is unexpected. It is this creative construction that underlines the importance and prestige of the object. The relationship between these two structures drives the innovative character of the design.

The skill of intuitively explaining a concept becomes essential in the early stage of creating a project, when an idea becomes explicit. A sketch depicting the design concept leading to the materialization of a building shows the architect's talent. The article examines case studies of objects built in recent years in Poland and in the world, in which such a relationship can be seen. The aim is to show the designers' motivation, the way of designing and realizing such buildings. This approach allows to outline, how creativity influences the design.

Keywords: *Architectural Design; Building Structure; Creativity; Surface Curvature*

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The Impact of Material and Technology on the Design of Wrought Iron Building Structures

István Vidovszky

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Wrought iron was an important material in historic times, which was mainly used for producing tools and weapons, however it also was applied for architecture purposes as building structures or building structure elements. In this article an attempt is made to analyse the impact of the material and technology of forging on the shaping and the design of wrought iron building structure elements form the time of the first known application to the first half of the 20th century, distinguishing five main era which are divided by four determining technological shifts in material production and consequently forging technology. Several phenomena are delighted regarding to the appearance of the artefacts and the characteristics of the material, which reveals the connection of the technology and the architectural design. The observations are validated by analyses of samples.

Keywords: *Wrought Iron, Building Structure Elements, Material Technology, Construction History, Forging Technology*

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Variable Refrigerant Flow Systems on USACE Projects

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Variable Refrigerant Flow (VRF) systems offer a unique set of advantages and disadvantages to a designer, contractor, and building owner. With the procurement requirements for the Government, additional challenges are introduced by these systems, and the systems are currently not permitted for US Army Corps of Engineers (USACE) projects due to requirements in mandatory design criteria. This research was performed to discover the major advantages and disadvantages of these systems, and to understand why they are not allowed on USACE projects. While performing interviews concerning these types of systems, two interesting case studies that demonstrate some of the disadvantages for these systems were discovered and will be detailed in this paper. Ultimately, it was discovered that VRF systems do not meet the public law requirement to provide open protocol control systems for U.S. Military projects. While the reasoning for this research had a particular focus on U.S. Military construction, much of the information presented will also be valuable to private entities considering these systems as well.

Keywords: *VRF, Variable Refrigerant Flow, Inverter Compressor, Efficiency*

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Skilled Electrical Labor Issues in the Mid-Western United States

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This research report aims to determine the status of the electrical workforce in the Midwest and identifying ways electrical contractors are overcoming challenges experienced with electrical skilled labor. The objectives of the report include evaluating contractors' perspective on the electrical skilled workforce in the Midwest region, complete a literature review on this topic which includes identifying the current status, causes of the labor shortage in the industry, and potential solutions to the skilled labor shortage in the United States, and determine the methods which contractors are utilizing to become less dependent on the quality/quantity of skilled labor available. The strategy utilized to complete these objectives include conducting a literature review to determine the current state of knowledge on this topic, holding pilot interviews to obtain both qualitative and quantitative data on the status of the skilled electrical workforce, and generating a questionnaire to be provided to a larger population to enhance the level of confidence in the previous findings. The literate review revealed a disconnect between the root cause of the skilled labor shortage and the steps the industry is taking to alleviate it. The construction industry must overcome challenges imposed by industry image and a push for all young adults to attend college. Attracting a younger and more diverse workforce is a primary solution to overcoming a skilled labor shortage. The pilot interviews on the status of the electrical workforce uncovered six main themes affecting the current workforce which includes demand, quality, age, materials, technology, and alternative labor. The questionnaire, developed from these six main themes, verified the need for additional research on this topic as many of the responses received were split 50-50 on these themes. Contractors are concerned about the number of skilled workers due to retire and it's not since they will need to be replaced, but rather the amount of skill and experience which is being lost. Younger skilled labor is perceived to be incompetent in working hard and completing quality work.

Keywords: *Electrical, Skilled Labor, Labor Shotage, Labor Demand*

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Alkalinity of Concrete Washout Water: A Pilot to Determine Jobsite Conditions for Potential Neutralization

Philip Street and **Paul W. Holley**

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The threat of stormwater contamination by concrete washout water from mixers, pumps, and other equipment has been identified through U.S. environmental policy for some time, primarily through the NPDES Permit Program. That said, enforcement of regulations prohibiting construction site release and spillage of this water has been sparse, at best. Recently, several urban areas and municipalities have begun levying fines upon general contractors for not taking proper measures to contain the washout water, and/or to properly dispose of it off of the construction site. This is prompting contractors, manufacturers, researchers, and other stakeholders to take notice, and to seek ways to mitigate the problem. This research continued the work of a recent project in which new containment product prototypes were developed, as part of a successful collaboration between construction management faculty and students, and their counterparts in industrial design. As the next phase of the study, this paper enumerates the findings of chemical analyses of washout water to develop a baseline level of contaminants. Primary contaminants measured include pH/alkalinity, total suspended solids, chlorides, oil and grease, and others. The authors' hope is that these findings will present a future opportunity to leverage textile, absorbents, and/or flocculants such as naturally occurring tree cellulose as potential neutralization strategies.

Keywords: *Washout; Environmental, Concrete; Alkalinity; Containment*

1 July 2019, 14:15-15:30

Creative Management: Zoltán Sebestyén

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Evaluating Performance of TQM Management in Mechanical Construction in the UAE

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Construction productivity has been a recurring problem throughout international construction. Stagnant productivity increases project costs and bid prices, jeopardizes completion dates, and adversely impacts safety and quality during project delivery. Reduced productivity can result from a variety of labour, management and sector/process factors. Management techniques can be argued to have the greatest potential for productivity increase and thus the focus of this study. Specifically, research was undertaken to explore the effectiveness of using Total Quality Management (TQM) in a middle-eastern context. TQM approaches have been proven to provide positive impact and to increase productivity in both controlled manufacturing and in construction activities. Nevertheless, the approach has been seldomly used in the (United Arab Emirates) UAE or the broader Middle East. Past efforts have demonstrated the effectiveness of TQM-based approaches on electrical subcontracts for commercial development and, using a similar approach, results are expanded to evaluate mechanical activities. On-going performance of teams completing like activities under a common schedule were evaluated and earned value data collected to compare the impact of active management to *status-quo* approaches, which are traditionally top-down and authoritarian in nature. Results are presented and compared to performance of electrical subcontracting activities to identify broader conclusions based on the research results. Future research efforts are outlined.

Keywords: *Case Studies; Construction Management; Productivity; Total Quality Management; TQM*

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Performance Based Maintenance of Multi Campus Critical Facilities

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Critical facilities such as healthcare, energy supply, and governance facilities are characterized by the importance of the continuous performance of these facilities, particularly: information and communication systems, power supply, HVAC, Fire Extinguishing and Water and Sewage Systems. It steams that maintenance and operation of critical facilities in general and large-scale multi-campuses critical facilities in particular is a multi-goal objective problem that combines at least three core objectives:

1. Maintaining a minimum required performance of the facilities in terms of continuous performance (e.g. energy, safety and security);

2. Minimizing the total costs of maintenance of the facilities given limited resources and subject to minimum required performance;

3. Minimizing the total costs of operations of the facilities given limited resources and required performance.

The research hypotheses are as follows:

I - Using Integrated maintenance and energy retrofitting model, the maintenance and performance of critical facilities can be improved due to the synergy between energy, maintenance and operation of facilities in general and of critical facilities in particular.

II – Multi-Goal Objective function that combines between the performance, maintenance and energy savings attains potential savings of 20-50% in maintenance and operations costs in facilities in general and in critical facilities in particular.

The objective function combines minimization of the costs, along with maximization of the energy savings and minimization of the maintenance costs. Constraints include minimum required performance for each facility and each system in each facility and minimum required energy savings. Multi-Choice Goal Programming and Supply Chain Management are used for the optimization problem definition. Integrated performance, maintenance, and energy retrofitting model for large critical facilities is developed and implemented. The research proposes integration of the maintenance and energy retrofitting of critical facilities and lays the ground for cost-savings and high cost-effectiveness in large-scale multi-campuses critical facilities maintenance and management.

Keywords: *Critical Facilities, Facilities Management, Multi-Choice Programming, Performance, Supply Chain Management*

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Factors Influencing Construction Time Delay on High Rise Projects in India

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In Construction Project delay can be defined as the time over-run from the agreed upon a time which can be written & signed in the form of contract or verbal mutual agreement. Construction Projects often face delays and uses unnecessary time due to various factors and reasons, and hence suffer from unfavourable consequences. This study will identify the significant delay factors from an intensive literature review, supplemented by delay factors in major Indian construction projects based on empirical data. A total of eight ongoing construction projects were selected for the study. And a questionnaire is also used to collect reasons for the delay, their frequency, importance, and severity. 53 valid responses received from the project managers. SPSS 21 tool package is used for statistical analysis and the tests performed were Severity index and the correlation between the attributes. The findings of the study concluded that the maximum severity for delaying projects is due to Design Variation followed by Lack of Proper Planning, and Shortages of Skilled Labour.

Keywords: *Delay; Projects; Construction Management; India*

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Examination of Advanced Fastening Systems for the Use of Robots in the Construction Industry

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Since robotics become more widespread in the construction industry, more construction phases and work steps must be covered with one robot system. Current robot systems are used almost exclusively in precast construction. At the construction site, so far only prototypes are in use, and only individual parts of the building shell construction and assembly can be covered. This paper examines to what extent fastenings are necessary to increase the operating range of robots and which boundary conditions exist or need to be addressed. Automated construction, and more precisely installation of fastenings, has so far been partially implemented, which has shown increased productivity as well as installation quality, thus load-bearing safety. This knowledge must now be extended to robots. The present work is based on an overview of current research and development and on the current research on a cable robot for brickwork construction at the university Duisburg-Essen. It further demonstrates that fastenings pose an important further application, especially in order to explore the extended phases towards the brickwork or contour crafting. It can be assumed that robots will become increasingly important in the construction industry. Reasons include high quality, safety, speed and economic aspects.

Keywords: *Advanced Fastening Systems; Fixings And Fastenings; Robots In The Construction Industry; Automatisation/Automation*

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The Strategic Application of Building Information Modelling (BIM) to the Role of Construction Project Management

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The iron triangle which contains time, cost and quality plays a very important role in the construction industry. Building Information Modelling (BIM) has triggered the way the construction industry operates and in particular 5D BIM. This dimension within the BIM model is more associated with the cost aspect of the iron triangle and the potential to be used by the constructional project manager or built environment professional to streamline workflows and increase the quality of services they provide to clients. 5D BIM encompasses the traditional 3D (three dimensional) model added to the 4D BIM time and then the costing as the fifth dimension. 5D BIM provides the contractor with the ultimate opportunity to produce accurate costs of projects, the expected timeline when the actual costs of the projects will occur, at the same time allowing the schedule to be optimised by taking into account the quantities of material produced from the 5D BIM model and the productivity rate of the project team. The 5D BIM model provides a great platform for the construction project manager to connect the processes of design, construction methods and costs; this on the other side calls for the construction project manager to embrace the digital transformation in the way quantity take off (QTO's) are produced. This research focuses primarily on the role of the construction project manager in South Africa whereby BIM is been perceived as merely being a software. The research method adopted a quantitative approach and qualitative approach were semi-structured interviews were conducted to get a clear picture of the digital transformation of the construction project manager professional. The findings show that in South Africa and in particular the construction project manager still use the old method of using Computer Aided Design (CAD) and 2D models to produce the costs. The research will be important for the construction industry and in particular for the QS practitioner to produce more accurate costs and thus productivity rate.

Keywords: *5D BIM; Building Information Modelling; Computer Aided Design; Construction Project Management*

1 July 2019, 14:15-15:30

Visualization, BIM:
István Vidovszky

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Micro BIM Adoption in Design Firms: Guidelines for Doing a BIM Implementation Plan

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Building Information Modeling (BIM) adoption is significantly increasing and is highly supported by governmental bodies because it has great potential for the construction sector. Nevertheless, some firms do not know how to proceed for implementation. Many design firms have also already adopted BIM, so feedback is now available: several research on BIM implementation have shown that there is a lack of understanding of implementation process and a need for guidelines. Moreover, these research work, case studies and action-research have not been cross-referenced in any significant way to deduce generic and adapted guidelines for firms that are now embracing BIM implementation. In this paper, guidelines for doing a four-phases BIM implementation plan are proposed, by referencing, cross-checking, comparing, and synthetizing case studies of BIM implementation in design firms and change management literature.

Keywords: *BIM; BIM Implementation; Micro Adoption; Design Firms; Guidelines; Implementation Plan; Change Management*

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Old Wine in New Bottle? A Study of Routine Change in Construction Firms with BIM Implementation

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Building information modeling is reshaping practices in the construction industry. However, less attention has been paid to understand the process through which new behaviors and organizational routines are developed around BIM implementation within organizational settings that are reinforced by the existing technological and organizational context. The reason BIM failed to yield the outcomes expected is because most of the industry view BIM merely as a new technology without appreciating the fact that it's actually reconfiguring their organizations and the wider industry context by affording radical new ways of organizing.

This research seeks to address this gap by identifying the processes through which organizational routines form and change over BIM implementation and finding ways whereby construction firms could configure their routines within the organization to better implement BIM. By drawing on organizational routine theories, we're able to unravel the sociotechnical process where people make interpretation and develop perceptions about BIM in their daily work, and how situated actions and interactions between individuals help to create and reshape organizational routines. The research used qualitative approach. Semi-structured interviews were conducted with different individuals from various parties involved in construction projects to identify and capture the perceptions, patterns of change in practice, and map the interactions between them.

Preliminary findings suggest that different actors have only partial understanding towards BIM due to the interpretive flexibility of the social groups in which they belong to. Successful implementation underwent an iterative process of different experts working across development silos to promote shared meaning, it required not only technical knowledge, but also social knowledge about who knows what. The result also revealed a power shift towards the end users. A thorough change management process right from project front end, and streamlining business to deliver true value of BIM is the new digital capability urgently needed in our industry.

Keywords: *Building Information Modeling; Digital Capabilities; Organizational Routines; Sociotechnical Process*

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Application of Building Information Modeling in Facility Management: A Case Study of a Commercial Project

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Adoption of Building Information Modeling (BIM) in Facility Management (FM) is effective for integrating Architecture, Engineering, and Construction (AEC) for providing better services to the end-users of a project for a whole lifecycle. Real estate sector in India has witnessed high growth in recent times with the rise in demand for commercial as well as residential spaces. Most of them are facing issues related to AEC and are not been able to manage such on-site problems resulting in delaying of projects. It is better to develop proper coordination to provide integrated information about AEC in advance to reduce conflicts occurring during the construction and operational phase. The operational phase of a building is the main contributor to the building lifecycle cost and estimates show that the lifecycle cost is five to seven times higher than the initial investment costs and three times the construction cost. There is a lack of real-life case studies on BIM in FM especially for existing assets even though new constructions representing only 1-2 percent of the total building stock in a typical year. So a case study of a commercial project is taken for Facility Management using BIM as a tool and analyzed for probable solutions for mitigating AEC conflicts. The findings from the study demonstrate that BIM value in FM stems from improvement to current manual processes of information handover; improvement to the accuracy of FM data, to the accessibility of FM data and in work order execution ultimately improving the sustainability of building construction projects.

Keywords: *Building Information Modeling (BIM); Facility Management (FM); Architecture, Engineering and Construction (AEC); Building Construction; Sustainable Development*

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Rethinking the Complex Refurbishment Project Attributes for Building Information Modelling (BIM) Adoption

Anthony Okakpu[a], Ali GhaffarianHoseini[a], John Tookey[a], Jarrod Haar[b], Amirhosein Ghaffarianhoseini[a], Attiq Rehman[a], Tongrui Zhang[a] and Dat Tien Doa[a]

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Uptake of Building Information Modelling (BIM) for complex refurbishment projects is foreseen as an essential resolution which will possibly increase the BIM adoption rate and eventually play a major role in transforming the construction industry. This anticipation is primarily based on the success of BIM with regards to complex construction operations, management, performance and productivity improvement. Various architecture, engineering and construction (AEC) key players have promoted the adoption of BIM and highlighted its significance in enhancing project delivery. Despite the envisaged benefits and feasibility of BIM adoption for complex refurbishment projects, many small and medium enterprises (SME) are still reluctant towards BIM. Though the incorporation of BIM in the New Zealand context is also similarly expected to move the construction industry forward, little has been reported in the literature to address the impact of refurbishment project attributes towards BIM adoption. A case study of tertiary education multipurpose facility project is adopted. Semi-structured interviews were conducted with informed project stakeholders and BIM experts outside the project based in New Zealand with the aim to identify refurbishment projects attribute and how it contributes to BIM adoption barriers for refurbishment project stakeholders in the construction industry in New Zealand. The benefit of this study is that it leverages the traditional refurbishment practice towards being BIM capable, and thus enable BIM uptake for refurbishment project stakeholders at the pre-maturity stage in New Zealand tertiary institutions.

Keywords: *Building Information Modelling (BIM); Refurbishment Project Attribute; Project Stakeholders; BIM Adoption Barriers*

1 July 2019, 14:15-15:30

Creative Scheduling:
Miklós Hajdu

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Negative Weights in the Network Time Model

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Time doesn't like to pass backward. That is why in common sense a negative duration (say: "time period") at first sight is hard to interpret. And, may be, it was the badly restricted computing and data storage capabilities of the early computers why the early network techniques (CPM/PERT/PDM) did not support presences of negative parameters and/or loops (potentially necessitating recursive calculations) in the model. After all, Monsieur Roy and Mr. Fondahl had definitively smuggled negative weights into network techniques when proposed nodes to represent activities of fixed or of estimated durations (MPM/PDM). Later on, introducing capabilities of negative lead and/or lag times the software developers (of IBM) apparently broke through the restriction of not allowing negative time parameters in the time model. Generalizing the network techniques and returning back to general DiGraph representation, where activities may be represented by (start and finish) pairs of nodes, releasing as many restraints on constructing a network time model as can be, letting multiple relations between pairs of nodes and allowing negative weights along the graph, a surprisingly flexible and handy network time model can be constructed that offers all the advantages provided by the above mentioned techniques. In this paper the authors review theoretical possibilities and technical interpretations (and use!) of negative weights in network time models while discussing almost 20 types of time-based restrictions among the activities of construction projects.

Keywords: *Graph Techniques; Network Techniques; Construction Management; Scheduling*

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Resource Levelling with Float Consumption Rate

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Istanbul Technical University, Istanbul, Turkey

The use of an appropriate scheduling method is not sufficient in constructing a reliable schedule. The management of resources is as important as the scheduling method. Inefficiency in managing resources may bring about severe delays as well as cost overruns caused by resource shortages in some cases and/or idle resources in others. Therefore, resources should be utilized efficiently in order to prevent project failures. Resource leveling is one of the approaches that are used for the management of resources. The goal of resource leveling is to minimize fluctuations, peaks and valleys in resource utilization without changing the completion time of a project and the number of resources required. Although the main principle behind traditional resource leveling is achieving an even flow of resources while the original project duration remains unchanged, it is possible to develop a more efficient model that discriminates among the activities that are selected for participation in resource leveling. For this purpose, a model was developed that considers the float consumption rates of activities. The float consumption rate is the percentage that is set to determine the maximum amount of float which will be consumed to shift the start time of the activity. The proposed model allows the scheduler to assign float consumption rates to each activity that can be used during the resource leveling procedure. When the required information is input, the proposed model automatically changes the required daily resources as it shifts the non-critical activities along their available total float times. The proposed model is expected to minimize the likelihood of severe delay and cost overrun. The model is demonstrated on an illustrative example by constructing a network and its resource utilization histograms.

Keywords: *Resource Management, Resource Leveling, Float Consumption Rate, Scheduling*

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Mining Daily Work Report Data for Detecting Patterns of Construction Sequences

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Sequencing construction activities in highway projects is a complex planning process which requires not only considerable knowledge and practical experience of the planner/scheduler about various relevant aspects, such as the activities themselves, construction and procurement processes, and construction methods, but also input from other key members of the project regarding specific constraints and requirements. Moreover, sequencing is an iterative process; the sequence developed in the planning phase is likely to change in the construction phase. Therefore, learning from as-built schedules of past completed projects is needed to improve the planning and scheduling processes for future projects. In current practices, most state Departments of Transportation (DOTs) still mainly rely on schedulers' experience for schedule development. A data-driven systematic approach is still lacking, although the highway agencies have been spending a significant amount of money, time, and effort to collect various digital data during the construction process. This study aims to leverage historical digital daily work report data available in the DOTs' database to detect patterns of construction sequences in highway projects. Daily work report data collected from a state DOT were used to conduct a case study that developed a Sequential Pattern Mining algorithm to extract frequent sequential relationships among the activities for one major type of highway projects.

Keywords: *Activity Sequencing; Construction Sequences; Daily Work Report Data; Project Scheduling; Sequential Pattern Mining*

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Ontology Assisted Collaboration Sessions on 4D BIM

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[b] *UMR n°3495 Modèles et simulations pour l'Architecture et le Patrimoine Centre de Recherche en Architecture et Ingénierie – MAP-CRAI, Nancy, France*
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Stakeholders use 4D modelling during construction to coordinate project data and collaborate effectively. The collaborative sessions between project stakeholders have a complex dynamic. This research was conducted under the scope of the 4DCollab project, which aims to improve 4D BIM supported Synchronous Collaboration Sessions (SCS) by adopting a user-centric approach, whilst considering specific 4D use-case information requirements. Following several experimental SCS, an initial ontology model was developed. This model offers a holistic view of the dynamics between the following main concepts: the meeting itself (session), its participants (users), the 4D BIM model and the collaboration devices used for decision-making. Several existing schemas within the BIM domain were identified and considered for the definition of the proposed ontology, re-using several already validated concepts. The 4DCollab ontology is introduced following a rigorous design methodology. Its applications, limitations and future work are also outlined and discussed.

Keywords: *4D; BIM;Ontology; Decision-making; Collaboration; Linked Data; IfcOwl*

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Economic Based Limited Resource Scheduling Algorithm

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Activity networks have been widely used in the planning, management, and control of building construction projects since their introduction in the 1950s. As the popularity of activity networking procedures has grown, so has the theory underlying the various procedures. Procedures are presently available that consider both technological and non-technological constraints and offer solutions solved optimally or heuristically. However, activity networks typical of building construction projects have not lent themselves to efficient optimal solutions because of their size, complexity, and diversity. Therefore, various heuristic scheduling procedures have been developed to solve this class of problem pragmatically if not optimally.

A disadvantage to the heuristic scheduling schemes available is that they follow a set of rigid heuristics and therefore may not be sensitive to a variety of differing network types or a variety of constraints. This study undertakes the development of a scheduling procedure that is heuristically based but that is sensitive to any variety of network types or constraints imposed by the scheduler. This is accomplished by combining all pertinent factors through a utility analysis and scheduling each activity based on the results of this analysis. The factors that are considered pertinent for the purpose of this study are the activity times based on technological constraints, network complexity, resource usage and availability, resource unit cost, and total activity cost. These factors are combined through the use of a cumulative utility model and prioritized to yield a scheduling sequence.

Keywords: *Heuristic; Limited; Resources; Scheduling; Utility Theory*

1 June 2019, 16:00-17:30

Creative Management: Edgar Small

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Competitive Strategies of Thai Contractors in Construction Project Management in the CLMV Countries

Thippawan Boonyaperm

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CLMV countries, namely Cambodia, Laos, Myanmar and Vietnam, are potential overseas markets for Thai contractors. Since the CLMV countries are in the developing stage, there are many construction and infrastructure projects emerging in order to develop economic growth of those countries. Therefore, it is an opportunity for Thai contractors to enter the CLMV construction markets. The study aims 1) to study the conditions and factors underlying in the construction business and construction project management for Thai contractors who enter the CLMV countries, and 2) to establish the competitive construction management strategies that could be adopted by Thai contractors in the CLMV countries. This study is a qualitative research. The population is divided into 2 groups, one is the senior executives of Thai contractors who manage their construction projects in Laos or Myanmar, the other is the project owners or stakeholders in construction industry of the studied nations. Data collection instruments were the interview forms and data analysis used content analysis. Research findings revealed that the construction industry in CLMV countries are still in high demand of construction projects. Strengths of Thai contractors were time and quality management while weaknesses was price management. Therefore, Thai contractors should play their roles by using differentiation strategies and niche strategies.

Keywords: *CLMV Countries; Competitive Strategy; Construction Project; Project Management; Thai Contractors*

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Comparison of Key Project Performance Indicators of Different Construction Sectors in Terms of Collaboration and Integration

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There is strong evidence to suggest that the use of collaboration and integration principles and methods improve overall project performance in the construction industry. Commercial Integrated Project Delivery (IPD) and Civil Infrastructure Alliance Contracting have specific collaboration and integration principles that define each as a unique delivery method. This paper investigates the similarities and differences between IPD and alliancing in terms of their key principles and explains the differences using the inherent differences between the construction sectors that have dominantly used each of the project delivery methods. The study uses 14 key performance indicators that are typically used to measure the performance of construction projects categorized into a) design optimization and b) construction risk management. The study concludes that IPD is more preferable for projects that require design optimization as the major KPI while alliancing might be more suitable for projects that deal with a significant amount of construction risks. The findings of this study can serve as a guide to properly identify collaboration and integration principles that will allow for better and enhanced project performance in a specific construction sector.

Keywords: *Integrated Project Delivery; Alliance Contracting; Integration And Collaboration; Project Performance; Project Delivery Method*

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Dynamic Planning of Construction Site

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Dynamic planning of a construction site is an unexplored part of a project execution process, according to its absence in literature. The aims of this study are first to highlight this issue basically in linear construction projects and secondly to explore its value through practical applications. For this purpose, factors that influence the selection of the construction site location and then the costs resulting from this selection are examined. The location which maximizes the production rate is investigated. The location must simultaneously minimize the non-productive time/cost and adhere to project's technical specifications. According to the project's time schedule, the "ideal" site location is explored at time intervals taking into account the work progress. The optimization method that is presented aims to minimize the cost that arises from the site non-productive time/cost and site relocation cost as part of the total construction cost. The validity of the model is tested in two real case studies. The first study investigates a vertical axe to Egnatia Odos Motorway (5.5km) and the second regards a section of Egnatia Odos Motorway in North Greece (15km). The results show that for the second project the relocation is required, with a profit of 100.000 €, whereas for the first one, relocation has no profit for the contractor. The concluding remark is that during the planning phase of linear projects, a study of dynamic site location should be performed in order to investigate whether there is a profit for the constructor from the relocation of site or not. This profit could cover expenses of financing according to the project cash flows.

Keywords: *Dynamic Site Planning, Relocation Profit, Optimization, Cash Flows*

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The Future Role of Facilities Managers in an Era of Industry 4.0

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The job description of asset and facilities managers continue to evolve. The future roles of facilities managers is somewhat a concern, given the trend and progression of innovative technologies in recent times. This study sought to evaluate the perceptions of built environment practitioners, involved in management of infrastructure during operations, regarding the influence of technological innovation on the future roles of facilities managers in terms of sustainability. An interview guide was used to solicit information regarding the future roles and responsibilities of facilities managers. The interviews were conducted with five facilities management practitioners selected purposively and conveniently based on knowledge, willingness and ability to participate in the study. Themes on the influence of innovation on facilities management practice and future adaptive roles of facilities management were evinced. These findings are envisaged to be useful in developing new strategies and directions to equip and accord facilities managers with the necessary techniques to adapt in this ever-changing era of technology and innovation.

Keywords: *Facility Mangers, Innovation, Johannesburg, Technology*

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Construction Experts' Perceptions on the Influence of Emotional Intelligence on Leadership Development

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Notwithstanding the significance of leadership within organisations and social settings, there seems to be less information about the influence of emotional intelligence on leadership development in the construction industry. The purpose of the research was to establish the influence of emotional intelligence on leadership and leadership development in the construction industry. The ongoing leadership challenge in the construction industry seeks research to determine the importance of emotional intelligence in leading teams. The research launched with an extensive review of literature in order to identify the core and sub-variables which embodies emotional intelligence and leadership for leadership development. A three iterative round Delphi technique was conducted to attain consensus of the identified emotional intelligence indicators. A list of experts was generated from peer-reviewed conference proceedings and industry executives. The rating of the influence was rated between low influence and very high influence. Data collected were analysed using Microsoft Excel, a spreadsheet software. The results indicated that emotional intelligence is essential and those that seek to think critically should show a different characteristics of emotional intelligence. The study contributes to the literature and empirical research underpinning on emotional intelligence in the construction industry.

Keywords: *Construction Industry; Emotional Intelligence; Construction Industry*

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Construction Site Layout Problems (CSLPs) on Portfolio Level: A Case Study

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Optimal layout planning of a construction site is essential for successful project completion. It can enhance productivity and safety, it can decrease cost and completion time, and many other goals can be defined according to the stakeholders' preferences. Unfortunately these goals can never be achieved at the same time: trade offs among the objectives are inevitable. The CSLP problem usually leads to a complex combinatorial multi-objective non-polynomial hard optimization problem which seldom leads to the finding of the optimal solution. Literature includes some analytical and a variety of heuristic, and meta-heuristic techniques for solving the problem usually focusing on minimizing the travel distance. A multi project environment with newly added optimization criteria and decision parameters defined by different stakeholders lifts CSLP to a level where researchers have not gone yet. This paper presents a case study on CSLP by showing the "Liget" project, Europe's largest cultural development, where different museum buildings and other cultural projects are executed partly parallel in a relatively small area. Due to the complexity of the portfolio, the known methods of CSLP were useless and in the lack of exact scientific methods the decision making process was extremely different, too. Some of the predicted and unforeseen factors that have affected CSLP are collected and presented.

Keywords: *Construction Site, Construction Site Layout Planning, Portfolio Level*

1 July 2019, 16:00-17:30

Creative Management:
Saurav Dixit

CCC2019 CREATIVE CONSTRUCTION CONFERENCE
29 June - 2 July 2019 | Budapest, Hungary

The Mind Mapping Technique in Project Management

Magdalena Bochenek

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This article presents the mind mapping technique which, despite many potential benefits, is still infrequently used in project management.

The case study provides practical examples for use of the mind mapping technique when implemented in construction projects.

The results of this study showed that the mind mapping technique helps project managers solve problems, define the scope of a project, schedule packages, and manage teams more effectively. Further, mind maps are useful for creating project plans, and for analysing existing plans so that they are easily understandable.

This study concludes that the mind mapping technique is a creative and useful tool for project managers. The mind mapping technique enables the project manager to gather, manage, share, and communicate information quickly and easily.

Keywords: *Mind Mapping Technique, Project Management, New Tools for Planning*

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29 June - 2 July 2019 | Budapest, Hungary

Design Criteria-Based Probabilistic Estimation Method for Aged Apartment Remodeling Projects in Korea

Jun Kim and Heesung Cha

Ajou University, Suwon, South Korea

As apartment get older, it is required to extend the life of the buildings through remodeling and reconstruction. In this situation, members of the apartment choose one of two options. The most important thing in this choice is economical feasibility, which is greatly influenced by the construction cost. There are many cases of reconstruction projects, and accurate construction cost can be calculated. However, remodeling projects are very rare and it is difficult to calculate accurate construction cost. In addition, the remodeling is not only difficult for the members to communicate the design criteria to contractors, but also takes time to reflect them in the estimation, which also affects the decision making. Therefore, this study proposes an estimation method that can integrate the design criteria with in cost. To do this, this study analyzes design criteria based on the previous remodeling cases and classifies them to derive Design Criteria that are required by the members. And it also proposes a range of construction cost by introducing range estimation process to measure the effect of construction cost on each design criterion. In conclusion, this study has been developed an easy-to-use estimation program by combining Excel and Sketchup software. If remodeling cases accumulate in the future, the accuracy and usability of the program are expected to increase.

Keywords: *Apartment Remodeling, Influence Analysis, Design criteria, Construction Cost, Estimation*

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Monitoring Distraction of Construction Workers Using a Wearable Electroencephalography (EEG) Device

Jinjing Ke, Jiayu Chen and Xiaowei Luo

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Department of Architecture and Civil Engineering, City University of Hong Kong, Hong Kong

Distraction is a major cause of unsafe behaviors and decreased safety performance in a high-attention demanding construction environment. However, few studies have drawn attention on cognitive characteristics of distraction and the method to detect it quantitatively. To fill the gap, this study investigates the correlation between distraction and mental activity using EEG device, aiming to provide a real-time approach to monitor the worker's distraction objectively. In this study, sustained attention to response task (SART) has been employed to induce the occurrences of distraction in the simulated construction safety inspection tasks. The recorded EEG data was divided into two groups corresponding with task performance: focused and distracted. By analyzing the data through pre-processing and feature extraction methods, the objective is to examine indices that enable to distinguish these two statuses based on time and frequency domain. The metrics proposed are estimated to be associated with cognitive functions like attention deficit and attention allocation, herein serve as an objective assessment of an individual's sustained attention degrees and cognitive failures. Accordingly, this study facilitated the development of cognitive features of distraction theoretically and made it possible to detect and control the inner distraction leading to unsafe behavior or decreased task performance in practice.

Keywords: *Distraction; EEG; Sustained Attention; Unsafe Behavior; Job Site Safety*

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29 June - 2 July 2019 | Budapest, Hungary

Developing a Lessons Learned Database for NCDOT Projects Using Design for Six Sigma (DFSS) Approach

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Valuable lessons and best practices learned from construction projects often fail to get transferred to future generations due to the lack of a formalized process. This perpetual problem gives rise to the need of imparting fresh training to new inductees once the aging workforce retires or in the event of turnover in an organization. This paper aims to facilitate the process of disseminating knowledge gained in the transportation area by developing a lessons learned database named Communicate Lessons, Exchange Advice, Record (CLEAR) under the auspices of the North Carolina Department of Transportation (NCDOT). A Six Sigma approach to Identify, Define, Develop, Optimize, and Verify (IDDOV) was used to develop the CLEAR database. The IDDOV model in Design for Six Sigma (DFSS) is a five-step process in designing efficient and robust new systems. The first phase involved conducting interviews with end-users as well as reviewing existing data within NCDOT data repositories such as claims and supplemental agreements data to better understand challenges and issues in need of resolution. With this information as basis, an outline for web-based database was created from which feedback was solicited. After taking into consideration all preferences from these end-users, the web-based database was fine-tuned to reflect all comments and suggestions gathered by the research team. This database is currently being populated from ongoing pilot projects. In the final stage of this project, the CLEAR database will be launched throughout the state on all ongoing projects. These five project phases reflect the principles of the IDDOV method of Six Sigma which provides the foundation for developing this database. Findings from this study will help NCDOT to institutionalize knowledge and improve project cost variations and schedule predictability. The success metrics include anticipated reduction in number of claims, claim amounts and increased coordination among staff within NCDOT.

Keywords: *Knowledge Management; Lessons Learned; Organization Efficiency; Six Sigma; Web-Based Database*

CCC2019 CREATIVE CONSTRUCTION CONFERENCE
29 June - 2 July 2019 | Budapest, Hungary

Process Reengineering using Activity Theory and Domain Mapping Matrix Method in Delivering Public Construction Projects

Hadif Alsuwaidi and Senthilkumar Venkatachalam

University of Sharjah, Sharjah, United Arab Emirates

The complexity of modern construction projects has been increasing due to the increased number of design disciplines, stakeholders, process and tools. In public project delivery, these complexities are further increased due to the existence of additional bureaucratic procedures. These decade old processes and the bureaucratic procedures left with dysfunctionalities, redundancies and non-value adding process wastes to the project outcome. This in-turn has a significant adverse knock on effect on the public project delivery in time, cost and quality outcomes. Hence, understanding the existing interactions and its complexity among the project delivery elements such as process, people and deliverables in public project delivery are paramount important to modifying the same to obtain the desired outcome based on the dynamic industry needs. In this proposed research, an example public project delivery department's existing workflow was captured using activity theory. Further, the existence of various people, process, deliverables and their interactions in the project delivery process were identified through an IDEF0 models. The identified project delivery elements and its interactions were then analyzed using a Multi Domain Mapping (MDM) method to evaluate against process dysfunctionalities, redundancies and wastes. In addition, the study also proposed an improved process flow by eliminating the above said discrepancies through a structured business process-reengineering framework. Further, the study validates the proposed framework through expert interview on the modifications made in project delivery elements. The proposed framework will be a guideline/ reference for similar business process reengineering exercise towards a public project delivery process in this region or in a similar context.

Keywords: *Process Reengineerin; Public Project; Multi Domain Mapping Matrix; Activity Theory*

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29 June - 2 July 2019 | Budapest, Hungary

Constructions of Liget Budapest Project: Unusual Solutions

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Museum building complexes can be found in numerous countries throughout the world. Among others, these include the world famous museum districts of the Museumsquartier in Vienna, the Museumplein in Amsterdam, the Museuminsel in Berlin, the National Mall in Washington D.C. and Millennium Park in Chicago. Liget Budapest will be constructed in line those benchmarks.

Regarding the architectural quality and solutions of the prospective museum, Városliget Zrt. will bring to the project the technological and functional concepts characterizing the designs (for example expected visitor enjoyment and museum technology solutions), the sustainability of the planned building (energy efficiency and ecology), relation to the surroundings (amongst other factors, green space considerations, relationship with the City Park and the building's accessibility) and the expected costs (both in relation to construction and maintenance).

To reach those objectives we have to use both conventional and creative solutions in the construction: e.g. technology of the 21st century is used to reconstruct architectural ornamental elements from residuals (House of Millennium), high level technological solutions are used at the museum building's waterproof insulations (House of Hungarian Music – architect: Sou Fujimoto), or very unique construction solutions are applied for the structural support system (New National Gallery – architect: SANAA). The world class architecture contain unique and unusual solutions of glass walls, structural geometry and extreme span. Some of these problems and the creative solutions used for overcoming these problems are discussed in the presentation.

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Creative Scheduling:
Zoltán A. Vattai

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Applied Decision-making Framework for Maintenance Scheduling in Bridge Management

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The deterioration of bridge structures in the United States is a national multibillion-dollar problem. Recent studies and reports show that almost 10% of these bridges need to be repaired or replaced. Therefore, facilitating decision-making for optimal bridge maintenance scheduling is essential for the management of networks of these aging structures where lack of preventative and proactive strategies cause significant consequences. In order to achieve such schedule, analytical methods are required to optimize conflicting factors over the life-cycle of the bridge while considering (i) structural performance and (ii) maintenance cost.

An advanced reliability-based decision-making framework for maintenance scheduling of deteriorating bridges is proposed. The outcome is a decision-making framework regarding repair and replacement of the structure over its life-cycle in terms of schedule and type of action to-be-performed on selected components considering system requirements, structure specification, as well as available budget. To implement the proposed framework, and in order to evaluate the performance of the developed methodology, a numerical experiment is developed. The results obtained by applying the methodology on an existing bridge are analyzed and the efficiency and advantages of the procedure are demonstrated.

Keywords: *Bridge Management; Reliability-Based Maintenance Scheduling; Decision-Making Framework; Multi-Objective Optimization*

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29 June - 2 July 2019 | Budapest, Hungary

Monitoring and Control Process of Construction Projects

Mamoon Mousa Atout

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Major causes of delays in construction projects are very common due to many factors caused by main projects stakeholders; client, consultant and contractor. Some of these factors are related to unclear objectives, risk identification processes, planning process, procurement process including tendering, construction process and supervision and lack of experience of performance measurement. Contractor's project managers of construction projects must be aware of work processes to avoid problem that may cause a delay of handing over the project. Some of these processes are project monitor and control. The research objective is to find out why process of project monitoring and control is major and important for project work progress and to determine the best practical techniques that can be utilized to track the work progress of construction project, and to make timely recommendations for required corrective action in response to any delays in the working detailed program. Monitoring project performance is a part of construction management processes that helps project manager to decide if the project can be delivered on time without any complain from the client. Project monitoring and control is important and essential for collecting the necessary information's that help projects managers to reviews progress regularly and help them to take any necessary action to avoid delays. The finding of the study shown the needs and actions required that must be considered by project managers to control internal process including essential techniques e.g. contractor selection criteria, operations of construction phases, control process, cost analysis, and labor and materials management. In the conclusion, internal control process is essential for contractor's project managers through appropriate and suitable effective utilization and adoption to the processes that must be identified at the beginning of the project.

Keywords: *Projects Managers, Monitoring and Control process, Risk Identification, Planning Process, Variances*

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Resource-constrained Scheduling in Repetitive Projects

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The optimal allocation of resources is a critical factor for the successful implementation of construction projects since it ensures stability in the work execution. Resource allocation is a complex optimization analysis, especially when it comes to linear or repetitive projects. In such projects, the Line of Balance scheduling method is preferred to the CPM-based scheduling. This study aims at developing a multi-objective model for optimizing resource allocation in such type of projects under different objective criteria and problem constraints. The practical implications of each criterion in terms of project cost are considered to provide some guidance on what criterion may be more suitable under particular circumstances. The optimization is obtained through a genetic algorithm formulation implemented in a spreadsheet form and with the use of a commercial optimization software. Indicative evaluation results are presented on the basis of a case study and show that criteria involving as decision parameters the cumulative exceedance of resources above a given resource availability threshold or the total number of resource movements in and out of the project may be the most appropriate to simulate actual costs and provide effective resource allocation solutions.

Keywords: *Resources Allocation; Resource Leveling; Optimization; Genetic Algorithms; Line of Balance Method; Repetitive Projects*

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A Mathematical Model for Quantifying Workers' Learning Range on Repetitive Construction Projects

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The role of planning and management in the construction industry has always been significant towards improving project schedules. However, the impact of planning strategies on different construction schedules poses a margin for development and enhancement, especially when it comes to managing linear schedules or schedules of projects undergoing repetitive types of work. Previous research efforts developed models to individually analyze the influence of congestion and the learning curve factors on linear schedules, but failed to capture the combined complexities and dynamics when integrating both. Therefore, this paper puts forward the groundwork of a scheduling optimization framework and presents work targeted at quantifying the learning development range of construction workers on repetitive projects. The ultimate goal is to minimize potential congestions by taking into account the inherent uncertainties of linear activities while considering the learning curve effect. More specifically, three dimensions of uncertainty are considered for each activity, namely at the level of the activity itself, at the level of the activity and its predecessors, and at the activity-network level. At the heart of the proposed mathematical model is a fuzzy-based system that generates a minimum percentage reduction in productivity boundaries for each activity with different uncertainty dimensions. The presented fuzzy system will, in future work, become the foundation of a time-cost optimization framework for linear scheduling methods.

Keywords: *Constructio; Linear Scheduling, Productivity; Learning Curve; Fuzzy Logic*

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29 June - 2 July 2019 | Budapest, Hungary

Comparison of Different Modified Shortest Path Algorithms for Traditional and Newly Developed CPM Networks: A Case Study

Levente Mályusz[a], Miklós Hajdu[a,b,c] and Zoltán A. Vattai[a]

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In the last four decades CPM project scheduling technique and its developments have been becoming the most frequently used construction management technique. Besides this technique has many shortcomings. Its inherent limitations in a real projects are partly handled with new developments – adding new relationships to the traditional ones - and Monte Carlo simulation which means, that scheduling algorithms should calculate project duration and the early and late start of the activities many times, so the speed of CPM algorithms getting more important. In this paper we compare different modified mathematical algorithms, Djiskrta, Bellman Ford, modified Bellman Ford, FIFO implementation, container implementation, for traditional and nontraditional – with calendar days, maximum types of the four precedence relationships (FS, SF, FF, and SS) - CPM networks. Comparison is based on artificial and real networks with at least 1000 activities. Results show that depending of the structure of the original network, different algorithms perform well, but modified label-correcting algorithm with FIFO implementations performs the best in many cases.

Keywords: *Critical Path Method, Precedence Diagraming Method, Time Analysis, Shortest Path Algorithms*

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Preliminary Results on the Time Analysis of Project Networks with or Relationships

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Precedence Diagramming, which has not changed since its development in the mid '60ies has slowly become the prevailing scheduling model during the last three decades due to its flexibility given by the four traditional precedence relationships. Recently new developments have improved the modeling capability of the technique such as non-linear activities and new types of precedence relationships such as point-to-point relationships, continuous relationships, relationships with logical switches (AND/OR relationships) or bi-directional relationships. Calculations in case of OR logical operators on relationships resembles to the job shop scheduling problems of production management and complete enumeration can lead to combinatorial explosion. The aim of this research is to define the limits regarding the size of the network and the number of OR where complete enumeration still acceptable and gives the optimal that is the shortest project duration within 5 seconds. Preliminary results based on 5 artificially created networks with different structures shows that the calculations can finish within 5 seconds in case of networks with around one thousand activities and 20 different options that is modeled with OR relationships , however, in case of 40 different OR relationships options or above that the calculation time will drastically increase to hours therefore new algorithms (exact or heuristics) must be applied.

Keywords: *Precedence Diagramming Method, AND/OR Logical Relationships, Combinatorial Enumeration*

Abstracts of poster presentations

CCC2019 CREATIVE CONSTRUCTION CONFERENCE
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P-01 | Architecture of Dispersed Multilayered Cyber-physical Robotic System for Coordination of Manipulating Robotic System Using UAV

Alexey Bulgakov[a], Daher Sayfeddine[b], Jens Otto[c] and Sergei Emelianov[a]

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Drone technology has demonstrated to be of great contribution to the construction field. Tasks such as photogrammetry, plot surveillance and assets inspections are successfully automated with the aerial robotic technology with some level of contribution of a human operator. In this paper we analyze the possibility to achieve fully automated construction task using dispersed robotic system: a drone and mobile robotic crane. The role of the drone is to study the surroundings and generate a desired trajectory for the crane boom arm in order to lay-in pergola blades. The paper focuses on the layers of the dispersed cyber-physical system allowing to achieve such complex task and optimize the trajectory of the crane boom arm by resolving two-dimensional ChebyshevGauss collocation method in order to have minimum-jerk path.

Keywords: *Cyber-Physical System; Drone; Trajectory Generation; Robotics In Construction*

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P-02 | Non-Destructive *in situ* Identification of the Moisture Content in Saline Brick Walls Using Artificial Neural Networks

Anna Hoła and **Łukasz Sadowski**

Wroclaw University of Science and Technology, Faculty of Civil Engineering, Wroclaw, Poland

The article proposes a method of neuron identification of the moisture content in saline brick walls of historic buildings, carried out on the basis of non-destructive testing. The method is based on the use of artificial neural networks, which were trained, tested and experimentally verified on a set of data constructed for this purpose. The set consists of test results that were obtained using non-destructive methods on a selected representative group of historic masonry buildings. Based on numerical analyzes, an appropriate type and structure of the ANN and learning algorithm were selected. Positive results were obtained, which indicated the possibility of using the proposed method in practice.

Keywords: *Budynki Zabytkowe, Mury Ceglane, Wilgotność, Badania Nieniszczące, Sztuczne Sieci Neuronowe*

CCC2019 CREATIVE CONSTRUCTION CONFERENCE
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P-03 | Innovative Stay-in-Place Formwork Method for Reinforced Concrete Columns

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Recent earthquakes at Pohang in Korea have caused significant damages to existing reinforced concrete (RC) structures. Particularly, piloti columns of RC structures suffered considerable damages. The objective of this research is to review the feasibility of an innovative stay-in-place formwork method using the Textile Reinforced Concrete (TRC) for RC columns in order to improve seismic performance and reliability. The scope of the study includes 1) a development of a concept for TRC stay-in-place form for RC columns, and 2) designing and manufacturing of TRC form modules. It is expected that structural damage of the property, human injuries or loss of life caused by future earthquakes can be reduced by improving the seismic performance using TRC site-in-place participating form, which can also save the social cost for the recovery from the disaster.

Keywords: *Textile Reinforced Concret; Stay-in-place Form; Seismic Performance; Reinforced Concrete Column; Earthquake; Piloti Structure*

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P-04 | Framework of Project Delivery System Selection Tool based on Cross Functional Relationship

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Construction project implements a typical project delivery method, procurement method, and contract types that have distinguished characteristics. Selecting the most sufficient method that has the benefits to success and reduces the risk of failure of the project has been a concerning point for project owners. This report is intended to suggest a framework of a project delivery system selection that considers the correlation between the project delivery method, procurement method, and contract types. The application of the tool for the owner will be in two steps. The first step to set up the initial goals and risks of the project to properly evaluate the tools and second step for answering the checklist questions based on the goals and risks that were set by themselves. As the characteristics of each type of delivery, procurement, or contract are defined from previous experience, our tool suggests the prior option of selection combination that can aid the owner's decision.

Keywords: *Combined Project Delivery System; Project Delivery Method; Procurement Method; Contract Types*

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P-05 | Application Development to Reduce Generation Time for Punch List

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With the recent improvement in the quality of life, more and more people are now demanding higher quality in terms of construction projects. Accordingly, construction techniques and construction control techniques have advanced. Recently, various construction project quality control techniques have been introduced. However, due to the non-optimized processes, it is difficult to commercialize these techniques. The biggest problem of the existing task process is 'the duplicated input'. The 'input at the site', the first phase of the 'duplicated input', is entered by typing within the application. However, due to the characteristics of the tasks on a construction site, it takes a long time and thus is inappropriate. Second, 'the input at the office' is problematic as it requires manual input for each sentence. The first problem was improved by changing the on-site typing method to 'input by item selection'. The second problem was improved by using 'automatic sorting' for the on-site input within the application. When the improved task process was implemented in the application, the working hours were reduced by about 18.4%.

Keywords: *Quality Management, Application, Punch List, Reduction of Working Time*

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P-06 | Methodology of Real Estate Valuation in a Whole Life Cycle Context

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Valuations of real estate are widely used in financial and other markets. Valuation methodology is based on the workings of a free market economy. The value can be determined by a single valuation approach or by a combination of multiple approaches. In real estate valuation it is essential to understand the modelling of the economic potential of the property during the life cycle. The combination of theoretical knowledge with valuation practice has been implemented through cooperation with an international audit and consulting company operating on the Czech market.

The aim of the project is to describe the life cycle of real estate from the point of view of the appraiser and identify the key assumption affecting the valuation methodology used for real estate valuation.

The outcome of the project could be used by real estate valuation experts as a guideline for choosing the appropriate valuation approach.

Keywords: *Real Estate Valuation; Life Cycle; Valuation Methodology; Change in Value; Development Property Valuation*

CCC2019 CREATIVE CONSTRUCTION CONFERENCE
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P-07 | Estimating Eccupancy- and Space Utilization Rates in Non-residential Buildings Using Planned-activity Data

Matti Karjalainen, Juho-Kusti Kajander and Matti Sivunen

Boost Brothers Ltd, Helsinki, Finland

Occupancy- and space utilization rates in non-residential buildings are often used as a metric for building efficiency. However, these rates are typically measured only for buildings already in use, at a stage where optimizing the size or layout of a building to improve efficiency becomes increasingly challenging and expensive.

The aim of this exploratory study is to describe a method for estimating the occupancy- and space utilization rates in non-residential buildings using planned-activity -based data. Such a method enables the client to obtain estimates of the occupancy- and space utilization rates already during the design phase of a building, when size- and layout -related changes are more easily and affordably executable. The method is best applicable to buildings with a high degree of usage predictability, such as educational establishments.

The research design of the study is based on a descriptive embedded single case study. In effect, the activity-based occupancy- and utilization rate estimation method is applied in the context of evaluating a building layout during the design phase of a school building project in Southern Finland. The main finding of the study is that an ex-ante estimation of occupancy and space utilization rates facilitates in optimizing the building layout during the design phase to improve its efficiency during the usage phase. Moreover, the results suggest that the developed method helps clients to improve project scope management and building value in use.

Keywords: *Building Efficiency; Building Value; Occupancy Rate; Project Scope Management; Space Utilization Rate*

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P-08 | Comparison of Perceptions About Women Managers Working on Construction Sites

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Recently, women's social participation has increased. In Korea, the proportion of women in each field is increasing, including that involved in architecture engineering. However, most women who are engaged in construction engineering tend to avoid working on construction sites. Therefore, the proportion of women managers working on construction sites is very low. Despite these problems, there are few studies on the situation of women working on construction sites. The purpose of this study is to examine the reasons why women managers avoid working on construction sites and to compare the perception about women managers working on construction sites. By doing this, construction site organization management methods could be suggested for improving the proportion of women managers working on construction sites.

Keywords: *Women Manager; Awareness; Organization; Comparison; On-site Working*

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P-09 | Analytic Hierarchy Process-based Model for Estimating Probability of Human Error in Design Stage

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The building information modeling (BIM) technique is used widely in construction. In general, BIM can prevent interference between different types of construction activities in advance, thereby reducing the cost of reconstruction. While it is clear that a decrease in the number of requests for information in the construction stage would have obvious benefits, there is a need to determine the effects of the investment from the planning stage. Therefore, in this study, a procedure for quantifying the design errors that occur at the design stage is proposed considering the probability of the human errors concept. To achieve this, factors for evaluating human errors can arise during the drawing stage. Based on these factors, an analytic-hierarchy-process-based human error probability estimation model is suggested. Based on the factors affecting the error in the design stage, we construct a hierarchy and calculate the relative importance based on the probability and assess the effectiveness of each risk control option. It is expected that if the model presented in this study is linked with the loss cost data for each factor, a loss estimation model at the design stage can be developed.

Keywords: *Analytic Hierarchy Process; Building Information Modeling; Return on Investment; Human Error Estimation*

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P-10 | Artificial Intelligence in Construction Management – a Perspective

Wolfgang Eber

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Efficient organization of construction services seems to be a complex task, limited by the capabilities of human intelligence. During the seventies based on e.g. the development of fuzzy technologies by Zadeh, the rise of expert systems gave new hope to innovative approaches to solving complex situations in project management. As history teaches, since then no real advance could be observed regarding this concept. Nowadays construction and real estate projects have become larger, thus more complex and risky, time schedules have become tighter as have the available budgets. With this the need of support of the organizational challenge has increased significantly. In this context and supported by the presently available computing power as well as on the basis of a presumably complete model of the building including the construction process with an Building Information Model (BIM), the idea of support by Artificial Intelligence has gained importance again and new hopes as well as fears have come to life.

Prior to explicit attempts to construct tools for construction management, an investigation of the principal needs of organizational support as well as the possibilities provided by Artificial Intelligence is required in order to prepare the ground for future development.

In this paper the principle understanding of complexity based on locality developing into emergent behaviour of the organization of construction projects is presented and mirrored to the expectance towards artificial intelligence operating on a Building Information Model (BIM). This investigation makes use of the theory of systems to model the behaviour of complex systems as well as of commonly used approaches offered by artificial intelligence concepts, e.g. neuronal networks, machine learning algorithms and rule-based decisions within a complex context. On this background the feasibility of improvement in gaining efficiency in construction management organization is elaborated and reviewed.

Keywords: *Building Information Model (BIM); Complexity; Construction Management; Real Estate Management; Artificial Intelligence*

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P-11 | Development of Planning-stage Feasibility-assessment Model for Extension Remodeling Projects of Old Apartment Buildings

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The government has continuously amended and developed laws for the vitalization of remodeling apartment buildings against the backdrop aging buildings. Despite such efforts, however, extension remodeling has not yet been used. Even though there are various issues causing this shortcoming, the present study focused on the fact that there is no instrument for reliable feasibility analysis and decision-making in the early stage of remodeling projects, thus proposing a remodeling project feasibility-assessment model. Generally, a feasibility (profitability) judgement is made after a design proposal is derived, and because decision-making for the implementation of remodeling projects is determined at the initial stage of implementation committee, a feasibility analysis model for projects at the planning stage is necessary. In this work, construction cost, project cost, financial expenses, and general sales revenues are calculated using remodeling project variables derived through existing apartment complex information, consultation, and research, and an algorithm was developed that can calculate approximate return on investment and the share of expenses of resident union members using the calculation results. In addition, the applicability of the model was tested by applying the developed early stage project feasibility analysis model to three cases already implemented. When the model was applied to three cases, the errors between the values predicted by the model and the actual values of the cases were 5% or less, indicating high reliability of the model. The model is expected to become a useful tool in practice if the applicability of the model is further proven by increasing the number of cases in the future. The project feasibility-assessment model developed in the present study will enable smooth implementation of projects by supporting residents' rapid decision-making. Moreover, if the model is variously applied by region, it is also expected to contribute to the policy establishment of local governments that identify the scale of apartment complexes in which extension remodeling projects are possible and support the remodeling.

Keywords: Remodeling Of Old Apartment, Extension Remodeling Project, Feasibility-Assessment Model

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P-12 | Further Relevance Analysis of a General PMO Model

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In our previous publications at this forum, on the one hand, we introduced and described a comprehensive project management offices (PMOs) model, and on the other hand, we conducted a deeper analysis of two elements of our model. With this series of articles, we are trying to underline the lack of the common categories and the conventional interpretation leading to a diverse discussion on PMOs.

Our suggested PMO model contains six elements formed in a Celtic cross shape. In our latest paper we made a deep analysis of the typology and the service categories. The analysis was not only based on a qualitative literature review, but we have also used the publications as an input for a quantitative analysis.

Continuing this approach in this presentation, we will dive deep in the remaining four elements of our model. The viewpoints and inputs for our analysis:

Category of Context (the environment of the PMO): industry and business model dependencies, impact of the organizational project knowledge and culture, PMO trends and PMO surveys from different sources

Category of Internal processes (of PMO): attempt to define a common set of process group for PMO, features of portfolio management software products

Category Performance (the metrics PMO): success factors, KPIs, expectations, balancing among business, project and operational metrics or emphasizing some of them

Category Maturity: compering different PMO and project maturity approaches to set up a practical and general proposal. Beyond making our model complete with all six elements analyzed, the presentation gives a brand-new part with the analysis of the relationships and dependencies among the elements.

Keywords: *Project Management Office; Evaluation Framework; Maturity; Performance; PMO Processses; Services; Typology*

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P-13 | Applied Risk Management Techniques Under Changing Environmental Condition: Time-varying Risks and the TCQ Paradigm

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Although risk management has become an integral part of project management insomuch that its application is required even by standards (e.g., Practice Standard for Project Risk Management (2009)), yet it is usually left to project managers to define the required processes in detail and only little relevant methodological literature is available to provide further theoretical content. On the one hand, no study has been made on methodological details, and on the other hand, practicability has not been investigated comprehensively yet.

We developed a value-based framework, where risk factors are measured on a linear scale. However, the framework, more precisely the process in which the plan data are substituted by fact data, raises some questions.

In order to maintain a value-based risk management process, a continuous valuation method is necessary which is able to capture the value of the project in its current state. In finance, conventional approaches typically tie the current value to the market value based on the contracts in force, which are often not observable, especially in the early stages of the project. In contrast, plan-fact analyses are built on an inverse concept, as they address only realized payments and book value, while market value is ignored. Then, what mechanism can be used in the plan-fact analysis to evaluate plan data turned into fact data? The answer is complicated because we know that fact data are sunken in a financial valuation process, that is, those data become irrelevant. The question arises: is it the same in a risk management process? Also, eliminating the deviation of the fact data from the risk, can we recalculate risk with analytic methods or just with approximate solutions like a structured Monte Carlo simulation? If these questions are answered, they can lead to a new controlling tool that solves one of the most acute problems of current controlling methods: a complete lack of integration of risk management.

Keywords: *Project Risk Management, Risk Evaluation Framework, TCQ Paradigm*

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P-14 | Digital Construction and its Role in Driving the Circular Economy

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Digital technologies can be used at any stage of the life cycle of a construction project, from the concept of the facility to the final of its operation. Construction companies use more and more available technological solutions, increasing mobility and safety at the construction site and facilitating the construction process. Digitization is increasingly affecting the modernization of the building management and operation process, saving time, making decision-making easier, causing saving financial resources and reducing the costs of energy and materials consumption. Not only investment of construction entrepreneurs in internal start-ups has been observed, but also the reverse phenomenon, involving the interest of technology companies in the construction investment market.

The closed-circle economy allows economic growth while reducing and optimizing resource consumption - it deeply transforms patterns of production and consumption chains and designs business models anew. The aim of the article is to present the results of the literature review, from the angle of discussion of issues related to the digital technologies used in various stages of the life cycle of construction projects with the assumptions of a closed-cycle economy. three successive steps were carried out: (1) a search strategy was developed to systematically review the literature and collect a representative set of publications on the relation of circular economy to building and digital technologies applicable to the life cycle of a building facility using Google Scholar; (2) a list of publications in the ad-doc database was prepared in order to synthesize the literature review; (3) a subset of the literature reviews was organized, which enabled the acquisition of quantitative and qualitative data as well as information on the phenomenon of digital construction and the impact of this innovative change on the development of the concept of closed circuit economics.

Keywords: *Digitization; BIM; Construction Sector; Circular Economy*

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P-15 | Empirical Approaches for Assessing Key Factors Pertaining to Greenhouse Gas Emissions in Early Stages of Projects

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Since the middle of the 18th century, the entire world has been devoted to industrial development. Based on the development of industry, many countries around the world have achieved rapid economic growth. This resulted not only in economic growth but also a large increase in the amount of greenhouse gases (GHG), which is evident as climate change and environmental disruption. To overcome such adverse effects, this study focuses on assessing the key environmental factors at the early stage of a project for decision makers. To support this objective, the authors have collected 210 real road construction cases and investigated 23 dependent factors including design parameters and physical environment of construction projects. Subsequently, statistical analysis as factor selection and regression modeling is conducted to extract the key factors. As a result, a total of five factors are extracted: "Area of Rice field," "Total Project Cost," "Number of Bridges," "Design (maximum) Speed," and "Length of Earthwork" via regression analysis. Moreover, the proposed regression model accounts for 69% and 67% of the total variance of "Total Environmental Loads" indicated by R^2 and adjusted R^2, respectively, at 99% of the significance level. Thus, the proposed model is expected to play a positive role in the decision-making process based on mathematical and empirical evidences.

Keywords: *Greenhouse Gases (GHG); Environmental Variables; Decision Making; Regression Model; Planning Phase; Construction Projects*

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P-16 | Augmented Reality Application Supporting On-site Secondary Building Assets Management

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Secondary building assets management requires a large amount of information related to them. Nevertheless, building assets surveys are cost and time demanding, especially because they need long post-processing efforts in order to systematize collected data. Furthermore, with the recent transition towards the BIM methodology for building management also modeling building objects both in their geometric features and in their related information is a long process and error-prone task. Under these circumstances the possibility of performing the majority of operation on-site would definitely make the process more efficient and it would reduce errors. Augmented Reality (AR) with its capability of overlapping digital data to the real scene is the right tool to support operators on-site.

The proposed system has the aim of reducing the time of secondary building assets survey and provide a tool for the automatic enrichment of BIM models. An AR device (Hololens) with an embedded computer and a neural compute stick constitute the portable on-site system for the automatic recognition of assets objects, removing the necessity of reworking data off site. A trained Deep Learning Neural Network inside the neural compute stick performs the recognition providing the operator with objects features and position. The AR application inside the Hololens operates as an interface between the user and the digital information just created. Finally, data is stored in a NoSQL database linked to the BIM model so as to be available for further operations. The visually supporting information provided by the AR tool, the possibility of working on data directly on site and the portability of the system represent means for increasing efficiency in survey operations. First tests have been conducted so as to prove the feasibility of the system and its use on site without further equipment.

Keywords: *Augmented Reality; BIM; Facility Management; Building Asset*

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P-17 | Micro BIM Adoption: A Multi-Variable Analysis of Adoption within the UK Architecture Sector

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To date a comprehensive analysis of interactions among BIM adoption factors, stages of the BIM adoption process, and time (e.g. time intervals of a national BIM initiative) is still lacking. This research aims to profile BIM adoption by mapping such interactions. The analysis is performed for the UK Architecture sector, which was represented with a sample of 177 organisations. To achieve the profiling of BIM adoption in the UK architecture sector, the study uses the outcomes from two types of inferential analysis: an ordinal logistic regression test to identify the 11 top factors influencing the BIM adoption process; and correlation analysis among the 11 top factors at different stages of the BIM adoption process (i.e. awareness, intention, and decision) and across three time intervals (i.e. pre-2011 as the time interval preceding the announcement of the UK BIM mandate, 2011-2016 as the time interval for the implementation of the UK national BIM strategy, and post-2016 as the time interval within which the mandate entered into effect).

Capturing the interactions involved in the profiling of micro BIM adoption and assimilating the outcomes in a single model unravel a further understanding of the BIM adoption process. In particular, the results reveal a dynamic behaviour characterising the micro BIM adoption process where: (1) correlated pairs of adoption factors have a varying level of influence within each adoption stage; (2) the factors involved in each pair generally change across the two dimensions (stages of adoption, and time horizon); and (4) the pairs of factors influencing adoption stages over time often combine constructs from the three clusters of drivers identified in (i.e. Innovation/BIM Characteristics, External Environment Characteristics, and Organisation's Internal Environment Characteristics).

Keywords: *BIM; BIM Adoption Process; Micro BIM Adoption*

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P-18 | The Role of Product Eco-labels in Realising the Greening Agenda of the Construction Industry

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The proliferation of green products/materials in the construction industry (CI) have been traced to the global attention on sustainability. However, greenwashing and continuous specification and use of unsustainable construction products/materials keep restraining the transition of the industry towards the sustainable path. Hence, the need for efficient and effective assessment and labelling tools to provide reliable information about the environmental attributes of construction products/materials. This study sets out to examine the impact of green product eco-labels in achieving the sustainability goals of the CI. An extant review of the literature was conducted on the various available green product eco-labels in use in the industry. Findings revealed two significant types of eco-labels namely: single attribute and multiple-attribute. Specification and use of construction products/materials with household-named and reliable eco-labels by construction professionals and stakeholders is recommended, as this step has the potential of mitigating the negative environmental impacts of the CI.

Keywords: *Assessment Tools; Built Environment; Construction Materials; Green Building; Sustainability*

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P-19 | Biomimicry Interventions for Addressing Global Environmental Challenges

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Many damages have been done globally to the natural environment, all in a bid to providing essential amenities and addressing the infrastructural deficit. These actions have resulted in increased carbon footprint, excessive heat, loss of biodiversity, increase in pollutant level in the atmosphere, and fluctuating weather conditions among many others. One of the latest sustainability drives that aim to address the environmental challenges facing the world today is biomimicry. As a new field that seeks to study, extract and emulate the fantastic processes and mechanisms operational in nature, biomimicry has become the most accessible and available source of productive ideas and solutions to the global environmental issues. Currently, there have been records of sustainable and innovative technologies inspired by nature that provides solutions to these problems. This paper aims to create awareness around the selected few of the biomimetic solutions that address the diverse environmental challenges facing humanity with a focus on energy and water issues. Been aware of the existence of these nature-inspired innovative technologies and solutions and their mode of operation is believed will be a giant step in encouraging their adoption and implementation.

Keywords: *Assessment Tools; Built Environment; Construction Materials; Green Building; Sustainability*

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P-20 | Critical Traits for Effective Leadership Style in the South African Construction Industry

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Leadership is associated with certain traits or set behaviours that characterised the leader and which to some extent is essential for influencing others for maximum cooperation and productivity. In some cases, actions may speak better than words. People follow a leader not only because of what he/she says, but what he/she does or is made of. In other words certain qualities are responsible for effective leadership. However, researchers are still oblivious of which trait would always guarantee leadership success. Hence, the search for better leadership traits has continued to this day. Leaders may find themselves in demanding circumstances characterised with complexity, pressure, and uncertainties such as construction and its industry. In such situation, certain leadership traits may be critical more than others for a leader to make headway, as well as influence his/her subordinates towards salvaging the situation to a great extent. The main objective of this paper is to investigate the critical traits for effective leadership among construction professionals in the South African construction industry. The primary research data were collected through a structure questionnaire while the secondary data were collected from a detailed literature review. The survey was conducted in the Gauteng Province of South Africa. Respondents were construction professionals especially project managers. Respondents were selected using heterogeneity and convenience sampling techniques. Data from the questionnaire were analyzed using Statistical Package for the Social Sciences (SPSS) version 23.0 software. Values were represented with descriptive statistics (mean) and standard deviation and were ranked according in descending order. Findings from the study revealed that ability to communicate well is of the optimum importance for effective leadership. Other findings include organised, integrity, self-discipline, experience, courage, visioning, empathy, honesty, problem solving ability, passion, creative, self-confidence, flexible/open to change, ability to inspire/motivate, composure, decisiveness, action oriented, risk taking, foresight, teachable and charisma. The study contributes to the body of knowledge on the effects of effective leadership for optimum performance in the South African construction industry.

Keywords: *Construction Industry; Leadership, Leadership Traits*

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P-21 | Professionals View on Drivers That Enhance the Development of Remanufacturing in Nigeria

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This study seeks to determine the drivers of remanufacturing from the professional's view. The methodology used for this study is the quantitative methodology, a mean item score and a normality test to determine their views and finally used the Mann-Whitney test to determine the views of the professionals. Findings from this research method revealed that there was no significant difference in the way; professionals viewed the drivers of remanufacturing. Further discussed was the implication of the findings, which revealed that the major driver of remanufacturing in Nigeria is the creation of job opportunities, which is vital as Nigeria is presently grappling with a high unemployment rate. Finally, it was concluded with the role remanufacturing will aid with the high unemployment in Nigeria.

Keywords: *Separated by Semicolons*

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P-22 | A Framework for Lean Construction Supply Chain; Bibliometric Analysis Approach

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Lean construction supply chain is a project management technique adopted from the manufacturing sector aimed at improving the performance of the construction industry. However, it's implementation is confronted with some barriers in the construction industry such as; poor understanding of lean concept and absence of framework explaining the application. Therefore, this study developed a framework for lean construction supply chain adopting a bibliometric analysis approach. Bibliometric analysis is a statistical analysis of articles for revealing the school of thought, issues and problems in an area of study. The articles adopted for the analysis of this study were extracted from Scopus, Google Scholar and other online databases. The retrieved articles were inputted into VOS viewer software to reveal the network analysis. The analysis showed the significant countries and school of thought supporting the lean construction supply chain. The findings from the analysis showed that the construction industry in most African countries is slow towards the adoption of the lean concept. The network analysis showed that the practice of lean construction supply chain revolves around waste reduction, just in time, integration and pre-fabrication. This practice formed the variables used for developing the framework. The study recommends that further research should be conducted to validate the framework developed from the study. The study contributes to improving the practice of lean thinking within the construction industry.

Keywords: *Bibliometric Analysis; Construction Supply Chain; Lean Thinking; Lean Construction*

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P-23 | A Conceptual Framework for Sustainable Road Infrastructure Project Implementation in Developing Countries

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Evidently, no generally accepted framework, concept and constructs currently exist although notably a lot of research has been made in the arena of Sustainable Road Infrastructure Project (SRIP) implementation. As a matter of fact, there are differing views by scholars regarding the SRIP implementation theory thereby making it a hazy and vague concept which is still a subject of debate. Till date, there has been a varied understanding of sustainability in terms of infrastructure development. This paper introduces a conceptual framework integrating the existing frameworks while considering the gaps in the literature and suggesting other criteria to succintly help in addressing those gaps. The methodological approach adopted for the study was acontent analysis of published peer-reviewed journal articles discussing Sustainable Infrastructure Development. The conceptual framework herein introduced, defines the criteria and indicators to be considered in the implementation of SRIPs in developing countries. It subsequently shows the various constructs that influence successful implementation of SRIP in developing countries. The framework developed in this paper can be generally applied in the implementation of SRIPs in developing countries.

Keywords: *Conceptual Framework; Developing Countries; Sustainability; Sustainable Development; Road Infrastructure*

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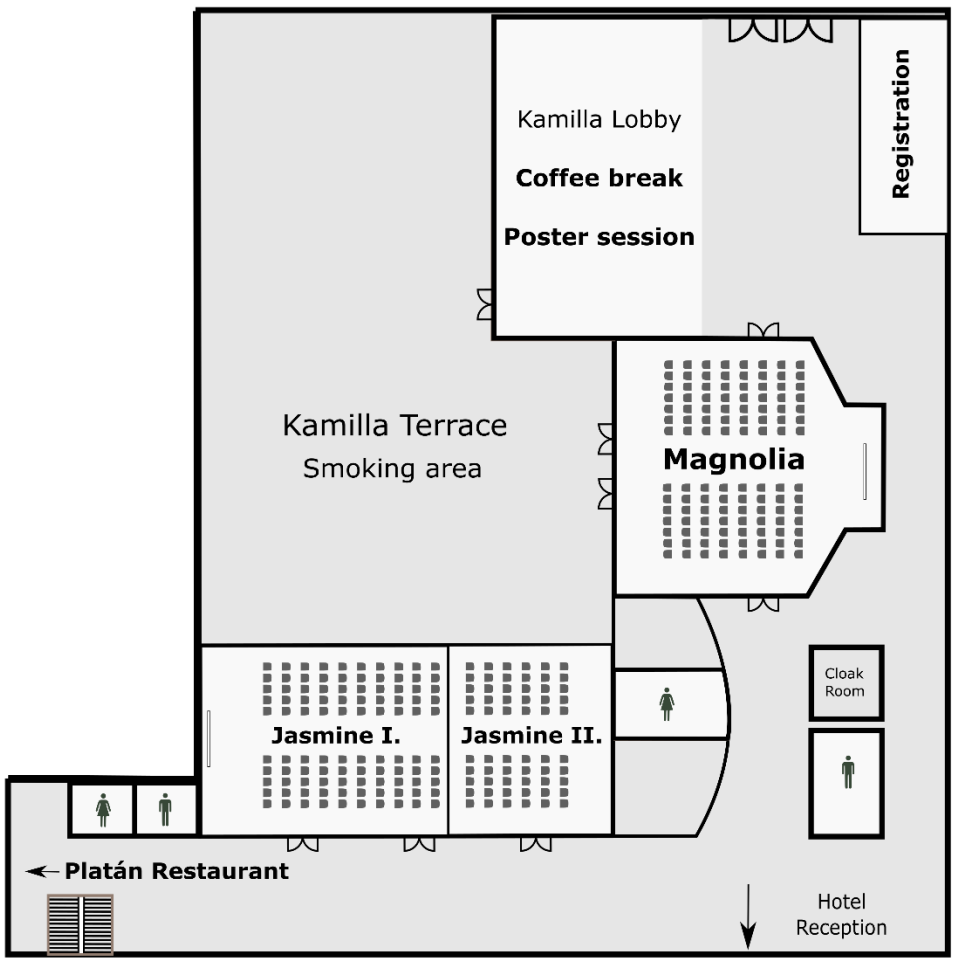

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