



CCC2018

**CREATIVE CONSTRUCTION
CONFERENCE**

30 June - 3 July 2018 Ljubljana, Slovenia



Final Program & Book of Abstracts

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FINAL PROGRAM (Including page references)

Saturday – 30 June 2018				
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Keynote Lectures

Shortcomings in Plain Vanilla CPM Schedules

Jesus M. de la Garza

Virginia Polytechnic Institute and State University, Blacksburg, USA

This talk will provide an overview of some of the challenges faced while interpreting results from the application of traditional Critical Path Methodology (CPM). The Lecture will focus on two distinct concepts, i.e., resource-constrained scheduling and single-duration activity estimates. These concepts are mainstream elements called for, explicitly or implicitly, in construction scheduling specifications. The Lecture will show why the Critical Path (or lack thereof) cannot be trusted without performing additional checks and balances and it will also demonstrate and explain, albeit theoretically and via simulation, why many construction projects overrun the baseline schedule. The Lecture will suggest mitigating **strategies for each of the challenges. In many ways, the Lecture will “burst the CPM bubble”** however, it will do it proactively because ignorance will never be an excuse. Knowledge is power, indeed, but its usage comes with immense responsibility.

Better (and within reason) design-construction interactions in a BIM world: challenges and opportunities

Daniel Castro-Lacouture

Georgia Institute of Technology, Atlanta, USA

A better built environment should portray better design-construction interactions. While good design is fundamental to the success of construction, good construction is also important to reflect fundamental design intentions, more so in complex, innovative projects. With increasing levels of diverse knowledge related to trades, materiality, shapes, spatial context, sustainability, interoperability, labor force, topology, etc., design-construction interactions are prone to information disruptions or conflicts that will surely lead to impacts in project safety, quality, cost and schedule. This presentation discusses new approaches, mostly enabled by building information modeling (BIM), for eliciting design performance information and how they intermingle with the ability to prevent conflicts while maintaining design intent during construction. From the not so distant attempts to automate and integrate information flows of materials and design information to current cloud-based collaboration formats, the presentation will also address the potential for using design performance information in optimization models, workforce management analytics, and process improvement. Implications to current educational practices will also be discussed.

The art and science of leadership in construction

Ghassan F. Aouad

Applied Science University, Sitra, Kingdom of Bahrain

Construction firms across the globe are facing serious challenges because of the economic downturn, changes in the political and social environments, and the pace of adopting innovative solutions. This paper will demonstrate how strong leadership can help construction firms cope with such challenges. People in our industry need to understand that leadership is in part art and in part science. In this paper, some frameworks for coupling leadership, innovation and competencies will be presented and discussed. In addition, the use of advanced IT solutions will be highlighted and the type of leadership required in this area of technological advancements will be discussed. The paper will conclude with a set of recommendations to help construction firms develop appropriate leadership styles and approaches that cope with the challenges in a fast changing environment.

Risk Management and Governance of Mega Projects

Tarek Bahgat

National Institute of Building Sciences, Washington, USA

Megaprojects are large-scale, complex ventures that typically cost a billion dollars or more, take many years to develop and build, involve multiple public and private stakeholders, are transformational, and have major impacts locally, regionally and sometimes nationally. This session will discuss the implementation of risk management qualitative and quantitative processes on an iconic \$16 billion mega project. We will discuss how Risk Management was integrated in the Governance of the Project and how technology facilitated the decision making process based on the risk outputs



chair: Edgar Small

Creative Management

10:00-11:00 Sunday – 1 July 2018

Opportunities and challenges in adopting higher strength reinforcement bars in reinforced concrete structures

Teng Hooi Tan

School of Science and Technology, Singapore University of Social Sciences, Singapore

The improvement in technology has enabled the strength of reinforcement bars to be progressively higher and a few developed nations have explored and embraced such changes in their construction industries. The paper outlines the opportunities and challenges faced by the Singapore construction industry in using a higher strength reinforcement. **While the Eurocodes, the nation's design code, allows GR600 steel to be used,** attempts to use to that strength limit have begun but there are still issues to be overcome before a wide spread acceptance and adoption can take place. Information from pilot projects on the use of such reinforcement shows that the benefits outweighs the drawbacks.

Keywords: reinforced concrete; steel reinforcement; high strength; challenges; opportunities

Entrepreneurship in the construction industry: key themes and factors to success

J. Mark Taylor, David G. McTier, Darren Olsen and Paul Holley

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In the dictionary entrepreneurship is defined as: “the activity of setting up a business or businesses, taking on financial risks in the hope of profit”. However, this definition does not even begin to scratch the surface for the work done in the construction industry. Construction companies are ever changing and, depending on each project that is embarked on, can be huge blessings or huge headaches. Behind every strong construction company is a strong competitor who is willing to put his or her name on the line with each and every project. These entrepreneurs are the backbone of the construction industry and without their willingness to lead the way, the industry would not be accounting for 798.10 USD Billion Gross Domestic Product in the fourth quarter of 2016. This study sets out to **discover common trends and qualities that accompany the construction industry’s most successful entrepreneurs**. The researcher wanted to discover what character traits and circumstances **set one up for success when it comes to starting and running one’s own construction company**. In order to do this, interviews were conducted with eight entrepreneurs who have built impressive businesses during their professional careers. These interviews lasted around thirty minutes each and the interviewees were given a list of questions before hand to look over and contemplate their responses. The interviews were later transcribed and combed through for further analyzation. Many conclusions were determined based off of the data that was received from the interviews. The interviewees revealed that the optimum time for someone to start a company in the construction industry is when they are in their thirties. The researcher also discovered that the entrepreneurs who had ten plus years of prior experience in the construction industry set themselves up for a greater chance at success. Furthermore, the biggest reason that each entrepreneur set out to start their own company was to have more control over their own decisions. Finally, the researcher also found that construction companies function the best when they are set up as s-corporations. Further research should look further into external reasons that entrepreneurs find success in the construction industry. Some of these factors might include overall industry health, key competitors or potential clients opening or closing their businesses.

Keywords: entrepreneurship; business; construction; contracting; success

Advantageous bridge construction with prefabrication

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In comparison to the extensive period of time spent within the engineering and procurement stages, very short construction period is almost always required. The usual reasoning by the public highway agencies (i.e. project owners) for that is the effort to cut the construction costs, while the road user costs are usually ignored. This paper discusses the advantages of the prefabrication on the construction site over the traditional cast-in-place approach mainly regarding the speed of construction. Its advantages include the acceleration of construction due to parallel production of the lower structure and bridge's supporting structures, minimum impact on the existing transport network, i.e. lowering the road user costs to the possible minimum, better quality control, higher durability of the resulting structure and often also cost savings via the economies of scale. Paper further discusses the development of the bridge building with the usage of the prefabrication approach in the Czech Republic and how the system of prefabricated beams and segments have evolved till today. This newly improved way of building bridges has proved to be **efficient even in the construction of the highway network's most demanding projects**. Technological improvements, such as the use of high-quality concrete or new generation of prefabricated segments which provide new bridges with a long service life with minimal maintenance needs are assessed. Transferring the main construction activities after completion of the lower structure outside the bridged area is proposed. In a permanent production plant, high quality concrete elements can be achieved thanks to the high stiffness of the mold and considerable manufacturing accuracy. The classic method of constructing bridges with a medium span of mounting in symmetrical brackets from segments have successfully returned between frequently used technologies and especially the speed of construction gives this technology a good perspective to the future.

Keywords: precast concrete; prefabrication; segmental bridge; speed of construction

An integrated multi-attribute-decision making approach for selecting structural system: a case study

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A structural system is the essential component of a building, which carries all loads acting on the building and transfers them effectively to the soil through the foundation. The design team, which includes engineers and architects, is in charge of determining the most **appropriate structural system that will fulfill the owner's and end user's requirements** as well as the legal requirements. Selecting the most appropriate structural system is a difficult task as there are many factors that need to be taken into consideration. Therefore, this problem can be considered as a multi-attribute-decision-making (MADM) process. This study proposes an integrated MADM approach for solving this problem, which uses the analytic hierarchy process (AHP) and Vise Kriterijumska Optimizacija I Kompromisno Resenje (VIKOR) methods. In the proposed approach, AHP is used to find the weights of the criteria and VIKOR is used to rank the alternatives. The proposed approach was employed in a real case. Extensive review of the relevant literature was carried out and the face to face interviews were conducted with four engineers of the design team, which was responsible for the selection process of structural system in the studied case, in order to identify the criteria that may affect the selection of a structural system from the managerial perspective. A total of 5 main criteria, namely the durability and safety of the project, the energy consumption, the project characteristics, the total cost, and the constructability problems, and 19 corresponding sub-criteria were identified. The findings of this study revealed that the proposed approach can be a useful tool in selecting a structural system.

Keywords: AHP;VIKOR; multi-attribute-decision making; structural system selection; case study



chair: **Ž**iga Turk

Creative Technology and Materials

10:00-11:00 Sunday – 1 July 2018

Potential impact of phase change materials on energy reduction in Army buildings

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Buildings account for approximately 40% of energy consumption in the United States with Heating, Ventilation, and Air Conditioning (HVAC). The Army is the largest building owner within the Department of Defense and has the ability to impact the energy consumption within buildings reported in the United States. To date, Army has been making great strides in building new construction and renovation projects to meet high performance sustainable building goals set by the federal government and have further adopted ASHRAE 90.1 and 189.1 standards. With these additional goals of achieving Net Zero Energy, **Energy Independence, and Energy Security to ensure continued support of the Army's Mission and** maintaining National Security, there is a need to continue to drive further energy reduction within these buildings. Phase Change Materials have been identified as a building material that has potential to impact more energy reduction within our buildings by providing a lightweight thermal energy storage solution that stabilizes temperature swings within buildings. This material, when designed with consideration of local climate and building thermal loads, can support reduced HVAC system sizing needed to meet interior thermal comfort requirements thereby driving greater energy efficiency of buildings.

Keywords: army; phase; materials; energy; HVAC

Advantages and disadvantages of trenchless construction approach as compared to the traditional open cut installation of underground utility systems

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The construction industry in North America is faced with the ongoing task of incorporating new technologies and management methods into their operations. New technologies and methods generally receive acceptance very slowly due to a number of factors. The risk of applying a new or unproven technology or method is sometimes perceived as being too high. Trenchless methods allow inspection, access, repair, expansion, upgrade, and installation of most underground infrastructure systems with minimum surface disruption. The tools that trenchless technologies offer range from robots to microtunneling and from closed-circuit television to cured in-place lining. The ability to select from these approaches **is hinged from knowing what is available in the market that will meet each owner's** particular needs. Knowing what advantages and disadvantages that the trenchless technology offers will provide an advantage to reach the right decision when selecting the appropriate approach. This research provides information on the advantages and disadvantages trenchless provides in five (5) areas, environmental, safety, traffic, business and cost impacts.

Keywords: safety, trenchless, underground utilities

Tunnels between continents

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Future transport may have to reduce the use of energy, especially the use of fossil fuels, this points towards reduction of transport by ships, aeroplanes and cars. Trains are a well documented way of transporting large volumes of goods as well as persons and it is assumed that the total use of energy would be very much lower than the earlier alternatives. Furthermore, the savings of surface area, airports and roads, would be considerable, the reduction of noise as well. Train connections across oceans and across wide bays and lakes, presents interesting possibilities of making present and future transport more efficient. By this paper the author hopes to raise interest for these promising and challenging possibilities. The proposed design of the tunnels may be seen on internet link below, page 10, the tunnel construction and challenges will be discussed in broad terms in this paper.

Keywords: tunnel, continents, crossing, deep sea, MAGLEV

Maintaining building function during a fire event: analysis of hospital fire and smoke control systems

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Fires in a critical facility such as a hospital could lead to catastrophic outcomes if the fire and smoke control systems are not properly installed, monitored, and maintained. This research studied a single facility and its smoke management system, primarily focusing on the HVAC system and how it responds in the event of a fire. Key facilities management staff were interviewed and national life safety codes were reviewed. The research indicated that each facility is going to operate completely different due to the differing needs; however, care must always be taken to properly locate functional hospital units in corresponding smoke zones to minimize the loss of a functional healthcare system after a fire event. Additionally, the need to digitize and centrally monitor all aspects of the smoke and fire control system is clearly evident, as this will provide a system that can be repaired quickly and efficiently.

Keywords: smoke, fire, control, HVAC, zone, damper, sprinkler, atrium



chair: Mirosław Skibniewski

Automation and Robotics in Construction

10:00-11:00 Sunday – 1 July 2018

Lunar construction solution: Chinese Super Mason

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Supporting the goal to develop the habitat for people to work and live safely and sustainably on the moon, the Lunar construction robot is typically designed with 3D printing system based on laser sintering technique with Lunar soil. Huazhong University of Science and Technology (*HUST*) propose a novel robotic system for Lunar construction entitled **CSM: the Chinese Super Mason**, combining on-site prefabrication of bricks and arch segments with Lunar soil and multi-structural automated assembly processes. CSM consists of a compound fabrication system composed of 6-axis robotic manipulator and automated sintering fabricator carried on an autonomous limbed vehicle platform. As a case study, a 2.8-m-long, 1.6-m-wide prefabricated structure for Lunar Base was successfully assembled with an experimental platform. Benefits and limitations of CSM and its experimental platform were identified and analyzed. Finally, prospections and exploratory steps toward the future of Chinese Lunar Base are also discussed along with the proposed CSM applications for Lunar construction.

Keywords: lunar construction; robotic construction; prefabrication; automated assembly; Chinese Super Mason

Critical analysis of factors affecting the on-site productivity in Indian construction industry

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The growth in construction productivity is low and do not continue for a long span of time. The purpose of the present research paper is to identify the factors affecting the on-site construction productivity, from the literature review and through a focused interview with industry professionals. The most relevant 18 attributes have been finalized for the study, and a total of 154 complete data collection is targeted for the study form major contractors, developers and consultants throughout India. The convenient sampling technique is used to collect the data. The collected data has been analyzed using relative importance index (RII) to priorities the variable on the basis of their relative importance. The findings of the study conclude that the most significant 3 attributes affecting on-site construction productivity are planning and scheduling, availability of material, and storage area for a material having a relative value of 0.78, 0.76, and 0.75 respectively. SPSS 21 software tool has been used to check the reliability of the data and to perform factor analysis. The factors are site management, competency management, commitment and coordination management, resource management, and planning explains a variance of 15%, 11.5%, 10.3, 9.1, and 7.1% respectively. The research paper attempts to provide an insight and better understanding of the factors affecting on-site construction productivity in India and the ways and means to control and improve construction productivity of construction projects.

Keywords: construction productivity; construction industry; on-site productivity; project management; and Indian construction industry

Smart technologies in the future housing constructions

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Art University of Isfahan, Isfahan, Iran

Researchers envision a future information society stemming from ubiquitous computing and intelligent environments. To a large extent, an ambient intelligent home called smart home no longer is science fiction and is technologically feasible. But reviewing the current state of the field shows that application of the smart home in real life and in the future housing constructions is still lacking; largely because the investigation of smart homes is limited to the domain of technical issues. But applying smart technologies in a home environment affects the way people live inside and outside of their home and shapes a new lifestyle. When the way of living changes the conditions of the dwelling change accordingly. However, usually the technology is added after the spatial design in the final design stage by the installation expert. Hence, a mismatch between the user demands and the smart home possibilities has been occurred.

In this paper, we turn this process around; the smart technologies are accommodated by spatial design and shape a smart home. Specifically, we model the new spatial characteristics of smart homes based on users' preferences. The model is based on the assumption that different individuals and households have different spatial preference of smart homes due to having various characteristics, lifestyles, and needs. A Bayesian Belief Network (BBN) is used for the modeling. It estimates the probabilities of choosing spatial characteristics of the smart home among different users with various sociodemographic characteristics. The spatial characteristics which are going to be predicted relate to the public-private layout of smart homes.

By determining new spatial organizations based on users' preferences, smart homes can practically provide spaces that respond to the users' needs in real life. Proper integration of technology with space and adjusted spatial conditions are vital for the accomplishment of smart homes and improving the users' acceptance.

Keywords: housing construction, smart technologies, technology-space integration, users' preferences

Rethinking the roles in the AEC industry to accommodate digital fabrication

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As robots and other technologies take over tasks previously performed by construction workers and planners, the concern about the future of jobs and wages will increase. While digital fabrication (dfab), and particularly the use of robotic technology, has the potential to improve productivity, it should not necessarily reduce total employment in the construction sector in the long run. It is expected that existing roles will evolve, mainly related to the human-robot interaction, and new roles will be created (e.g., in addition to designers there would be a need for employees with digital skills). Particular attention should be made to the transition phase in which conflicts may occur between the old and new systems and planning methods. This will occur for different functions and services during the planning and execution of construction projects. Focusing on the construction phase of a concrete wall using additive dfab for the NEST building located in Dübendorf, Switzerland, the different roles were evaluated. From this study, it seems that robotic technologies and conventional construction will coexist next to each other for a while, leading to a higher job variability and the creation of new roles, such as dfab managers to support coordination required, dfab programmers to develop computer numerical control that can be implemented with industrial robots, or dfab technicians to support robotic systems. However, there is still a lot of uncertainty, making it difficult to quantify employment impacts. Therefore, further research is needed to evaluate the impacts of using dfab to the functional division, supply chain and business models of the AEC industry, and to assess additional social impacts, such as changes in education schemes.

Keywords: construction automation; digital fabrication (dfab); human-robot interaction; industrialized construction; integrated project delivery (IPD); project delivery and contract strategies, robotic construction; roles in the AEC industry



chair: Keith Rahn

Creative Management

11:30-12:45 Sunday – 1 July 2018

Detection of unbalanced bids: a case study

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An unbalanced bid can be defined as a bid price that does not accurately reflect reasonable cost, contractor's profit, general overhead cost and other indirect costs. Selecting an unbalanced bidder as the contractor may lead to significant increases in the contract price. Therefore, detecting the unbalanced bids is a critical issue for owners. There are two main types of unbalanced bid, which consists of front-end loaded and quantity error exploitation. This study mainly focuses on the second type, namely quantity error exploitation, in which a contractor tends to increase the unit prices of items that are underestimated and reduce the unit prices of items that are overestimated because of errors in the estimated quantities. If an owner can detect the unbalanced bids during the awarding stage, a fair competition environment can be achieved. This study aims to provide owners with a model, which may assist them in detecting unbalanced bids. The proposed model uses five different grading systems. Owners may assign different weights to these grading systems and thereby the final score of each bidder can be calculated. All bidders can be evaluated based on the calculated final scores as well as the offered bid prices. The applicability of the proposed approach is demonstrated in an illustrative example. The findings of this study revealed that the proposed approach can be a useful tool for owners in detecting unbalanced bids.

Keywords: unbalanced bid; detection model; grading system; owner; case study

Improving efficiency and environmental impact applying JIT logistics and transport consolidation in urban construction projects

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The way in which construction logistics is organised has considerable impact on production flow, transportation efficiency, greenhouse gas emissions and congestion, particularly in urban areas such as city centres. In cities such as London and Amsterdam municipalities have issued new legislation and stricter conditions for vehicles to be able to access cities and city centres in particular. Considerate clients, public as well private, have started developing tender policies to encourage contractors to reduce the environmental impact of construction projects. This paper reports on an ongoing research project applying and assessing developments in the field of construction logistics in the Netherlands. The cases include contractors and third party logistics providers applying consolidation centres and dedicated software solutions to increase transportation efficiency. The case show various results of JIT logistics management applied to urban construction projects leading to higher transportation efficiencies, and reduced environmental impact and increased production efficiency on site. The data collections included to-site en on-site observations, measurement and interviews. The research has shown considerable reductions of vehicles to deliver goods and to transport workers to site. In addition the research has shown increased production flow and less waste such as inventory, waiting and unnecessary motion on site.

Keywords: consolidation, construction transportation, just in time logistics, logistics efficiency, urban construction projects

Factors enhancing practitioners' motivation in small local constructor in Japan

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In public construction procurement in Japan, the designated competitive bidding had been mainly used until the middle of 2000s. This scheme has many advantages such as being able to select a reliable contractor with low transaction costs. It has a disadvantage, however, of possibility to cause collusive bidding particularly under shrinking construction investment period. To enhance transparency in procurement, the general competitive bidding has been introduced since the middle of 2000s. However, this reform seems to have been lower motivation of practitioners. Under the designated competitive bidding, many awarded vendors were able and willing to do good works as much as possible, some of which were not necessarily specified in contract documents. Price competition was not much severe, and good works were certainly led to award of the next project. Under the general competitive bidding, however, vendors are neither able nor willing to do works which are out of project scope. Price competition is now severer, and good works do not necessarily lead to award of the next project. Currently, thus, many practitioners now tend to do tasks as written in the contract document with demotivated feeling. To motivate construction practitioners, thus, becomes an urgent topic for the Japanese construction industry. **This study conducted a field survey of practitioners' motivation in a successful small local constructor in Tokushima prefecture, Japan. This study identified several factors affecting motivation of local practitioners, including development and application of information and communication technology (ICT) well suited to the company and top management's attitudes to support employees. These factors enhance autonomy, competence, and relatedness of employees, which are three conditions for employees' intrinsic motivation. Employees' high motivation realized higher productivity and profit, which lead to high incentive. That is, there exists a cause and effect relationship between intrinsic motivation and incentive for company employees. The results hint a method of not only improving motivation of construction practitioners but also enhancing attractiveness of local construction industry in Japan.**

Keywords: motivation; ICT; local constructor; Japan

Generating a visual map of the crane workspace using top-view cameras for assisting operation

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All terrain cranes often work in construction sites. Blind spots, limited information and high mental workload are problems encountered by crane operators. A top-view camera mounted on the boom head offers a valuable perspective on the workspace that can help eliminate blind spots and provide the basis for assisting operation. In this study, a visual 2D map of a crane workspace is generated from images captured by a top-view camera. Various types of information can be overlaid on this visual to assist the operator, such as **recording the operation and projecting the boom head's expected path** through the workspace. Herein, the process of generating a visual map by stitching and locating the boom head trajectory in that visual map is described. Preliminary proof-of-concept tests show that a precise map and projected trajectories can be generated via image-processing techniques that discriminate foreground objects from the scene below the crane. These results show a way to help the operator make more precise operation easily and reduce the operator's mental workload.

Keywords: all-terrain crane, top-view camera, optical flow, image stitching

Determination of a classification tool for IFC data models based on a predefined classification system

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Open BIM models are generally based on the ISO-generic IFC (Industry Foundation Classes) data model. These data models only allow limited interpretations and evaluations concerning specific guidelines or standards. This paper presents a classification process for IFC data models, which allows adapting them according to country-specific classification systems. Ensuring that the different elements in a data model are adequately classified is particularly important for cost estimation during the early stages of a project. The proposed process allows assigning the proper classification even when the quality of the model is limited. The main steps include: (1) Analysis and understanding of the IFC structure, as well as a country-specific classification system, (2) creation of a classification tool for a country-specific cost structure using an IFC model, (3) creation of rules for quality assurance as well as the development of quantities according to a country-specific guideline for the development of preliminary cost estimates. The classification process was tested using IFC data models from construction projects to fit the classification standard for Construction Cost Plan for Buildings (Baukostenplan Hochbau (eBKP-H) in Switzerland). In particular, the classification was made **for the "Structural Work" group of the eBKP-H** using Solibri Model Checker and MS Excel. Results show that the proposed classification process was able to improve the allocation of the different elements to their correct category, reduce the number of unclassified elements, and ultimately improve the quality of the information used to do cost estimates.

Keywords: classification process; IFC; classification tool, building Information modeling, Solibri model checker



chair: John Smallwood

Sustainable Construction, Health and Safety

11:30-12:45 Sunday – 1 July 2018

Assessment of green building standards: identifying aspects/opportunities for future improvements

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Social problems and environmental degradation are the result of economic development in many parts of the world. Balancing social, environment and economic is the goal of sustainable development. Many countries have developed environmental assessment standards to support sustainable development concept. This paper presents a comparative study of green building evaluation standards in both developed and developing countries to find similarities and differences in order to make future improvement on each standard to full field sustainable development concept. The comparison is done by reorganize criteria listed in those standards to match BREEAM evaluation criteria for ease of study. The study found that most building evaluation systems focuses mainly on environment and then economic while pay less attention on social side and most criteria gives higher emphasis **to energy and environmental mitigation issues with “proactive” measures. For the future development of evaluation standard, social impact need to be improved and minimization of building material use need to be preventive more than reactive management.**

Keywords: green building standards; architecture; sustainability

Investigating the hindrances of implementation of occupational health and safety among Small Medium Enterprise's in the Gauteng province of South Africa

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A positive safety culture requires participation of all stakeholders in construction industry, and is shown through the safety-related knowledge, attitudes, beliefs, behaviour and practices of each worker. Therefore, the study is investigating the hindrances in the implementation of occupational health and safety (OHS) among small medium enterprises (SME'S) in the construction industry in the Gauteng Province of South Africa. A structured questionnaire was distributed to different construction companies and construction workers. From the 70 questionnaires distributed, 42 were brought back and they were all valid and usable. Findings from the survey results obtained from the chosen respondents revealed health safety was known and practiced, however, there are hindrances in the implementation such as poor regular inspections and audits, poor management, poor supervision, lack of material and components, lack of management commitment, equipment and tools, poor communication between workers, poor employers involvement, lack of training and risk education to name a few were the major hindrance in the **implementation of occupational health and safety among SME's**. Furthermore, if the challenges could be addressed appropriate and effectively result could manifest such as increased productivity; improve quality work; contractors growth and reduced claims; reduced accidents; reduced rework; improved schedule performance. Management and leadership at all levels are therefore encourage to improve construction OH&S in South Africa among SME's. **Moreover, occupational health and safety of the workers is not negotiable, is all pervasive, increases productivity, and leads to better performance, improve the company image, reduced claims and accidents also reduce lost times spent on injuries.** The concept of OHS implementation must be emphasized by the client and the consulting team by way of having occasional not once off, a major workshop to be held three times in a year, to increase the awareness and the seriousness of the implementation of OHS.

Keywords: occupational health and safety, small and medium enterprises, South Africa

Ecological and functional technical mortars with rubber

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The finishing coatings of buildings, such as plasters and renders, are essential for the durability and sustainability of constructive solutions. Mortars provide constructive elements with protection and contribute significantly to thermal and acoustic comfort of the indoor environment. The development of ecological mortars with specific characteristics in response to the need for more sustainable construction represents an important challenge.

Considering the current quality requirements for mortar industries regarding technical specificities and the environment, it is fundamental that more recycled or natural raw materials, and material with lower environmental impact are introduced. Furthermore, the development of multifunctional mortars suited for different substrates ensures more versatility of the products. Looking to address these issues, this paper presents the development of mortars incorporating granulated rubber from used tires. This residue has been considered for the development of construction materials due to its lightness, elasticity and energy absorption capacity. It also provides improved thermal and acoustic behaviour.

For this purpose, 2 different mortar compositions with fine rubber granulate were analysed. Mechanical behaviour for different substrates was determined through compressive and flexural strength, dynamic elasticity modulus and adhesive strength. The hygrothermal behaviour of the mortars was also evaluated considering the results obtained for water vapour permeability, capillary absorption and thermal conductivity tests.

Very promising results were obtained in this study. These allow the framing of these mortars in the recent context of CE marking requirements for rendering and plastering mortars.

Keywords: mortars; multifunctionality; recycling; rubber residues; sustainability

An investigation of the most waste-prone materials and waste causes in prefabricated steel structure building projects

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Prefabrication is the shifting of construction activities from traditional practices, with high level of waste, to industrial processes with minimum waste generation. Therefore, it is considered as one of the major improvements to minimize waste generation in the construction industry. However, the prefabrication process itself is associated with significant amount of material wastage; which increases the total project cost and time with negative environmental impacts. In order to take efficient measures in reducing the amount of waste at source, which is the initial step in waste management, it is essential to identify the most waste-prone materials and investigate the main sources of waste generation. The current paper presents initial findings of an on-going research on development of a process model as well as a decision support tool to predict and manage waste in prefabricated steel structure projects. An investigation has been carried out in collaboration with the Turkish prefabricated steel structure building companies to identify the most waste-prone materials and the main sources of waste generation. A mixed research method incorporating qualitative and quantitative approaches were adopted during the initial phase of the on-going study. A classified list of potential waste causes and a set of materials were formulated by a detailed literature review, studying real project records in a company and by interviewing with experts in the sector. A multi-phase questionnaire survey has been administrated to more than 30 professionals to learn about their perceptions on waste-prone materials, their sources and factors plugging the way of effective waste management within the prefabrication sector in Turkey.

The questionnaire results indicate that, sealing materials, dry wall boards, heat insulation materials, cables and paints are the five most waste-prone material groups. Also, the main sources of waste generation are identified; which reveals the dynamic nature of material waste causes. After the discussion of questionnaire findings, it would be proposed that considering the different sources of waste generation, impacts on project performance and mitigation strategies, an efficient waste management process model and a support tool should be developed for the Turkish prefabricated building companies in order to monitor and control waste generation.

Keywords: construction; material waste; prefabrication; waste causes

Application of heart rate variability for thermal comfort in office buildings in real-life conditions

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In the context of building energy efficiency, occupants' preferences can be considered as a source of information complementary to those in traditional building management systems (BMS). The general availability of wearable devices in recent years has increased interest in this ecosystem of technologies, as well as in their practical applications and those that can potentially derive from them. This study aims at investigating the applicability of wearable heart rate sensors for evaluating aspects of mood associated to stress/comfort, and in particular in relation to thermal comfort. A procedure for data gathering and analysis is proposed and tested in an office building in real-life conditions. First results show that no clear pattern of comfort vs. discomfort can be observed in data during testing. In addition, some of the challenges of applicability of the technique in real-life conditions are discussed in the study.

Keywords: Building Management Systems; energy efficiency; wearable device; heart rate variability; occupant comfort



chair: Thomas Bock

Automation and Robotics in Construction

11:30-12:45 Sunday – 1 July 2018

A novel approach to develop vertical city utilizing construction automation and robotics

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As a sophisticated organism, a city has an essential characteristic, which is the ability to constantly and flexibly transform throughout its lifecycle in response to economy shifts, demographic change, and environmental pressures. Nowadays a number of new **developments are claimed in the name of "vertical city", yet few represent this important** characteristic. This paper aims to propose a novel approach of vertical city, or in other words Dynamic Vertical Urbanism, featuring constant vertical urban transformation by applying the state-of-the-art construction technologies. First, successful and unsuccessful precedents of building complexes which inspire this novel concept will be analyzed. In addition, building technologies that are crucial to the implementation of this approach will be introduced. As a result, this vertical city concept has the ability to integrate five basic elements of a city: vertical and horizontal circulation systems as its paths, a flexible building envelope as its edges, variable mix-used functional blocks as its districts, sky bridges and roof gardens as its nodes, and the complex itself as a landmark. More importantly, it can change its size, form and function with the help of construction automation technologies and open building principles, and responsively evolve in accordance with social, economic, and environmental shifts in a self-sufficient manner, meanwhile avoiding the risk of being homogeneous with surrounding buildings. Finally, the complex will perform as a series of interconnected components which act together to form a living organism that performs various functions and purposes such as office, residential, commercial, school, hospital, police station, and infrastructure. In conclusion, this report will provide researchers, architects and urban designers with a valuable example for the future vertical city developments and beyond.

Keywords: construction automation; modularization; on-site construction factory; open building; vertical city; Vertical Dynamic Urbanism

Process information modelling (PIM) for public housing construction project in Hong Kong

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Public building construction, which consists of many sub-tasks and numerous systematised working processes such as planning, mobilisation, scheduling, procurement and controlling, is complicated. If the project team is incapable of managing these processes seamlessly, it may result in severe project delay and cost overrun. This issue becomes even more apparent when utilising construction robotics, since precise process and scheduling information as well as feedback is required to ensure each task is completed correctly and on time. Support in addressing these complex management activities in particular for the robotic usage offers Process Information Modelling (PIM). In this paper the process-oriented modelling approach, PIM, which provides a collaborative way of planning, designing, producing, assembling and entire project life cycle management strategy is introduced. The main objective of PIM is to integrate with the conventional Building Information Models (BIM) and supplement them with a process oriented database platform, allowing for smooth data transfer, as well as promoting seamless and constant data sharing among all stakeholders. Digital documentation, simulation and real-time data are produced progressively to support the decision-making process. The effectiveness of **the PIM is demonstrated on façade painting task by a painting robot for an on-going consultancy project commissioned by the construction industry council (CIC) in Hong Kong.** The impacts of PIM on supporting the potential future applications of construction robotics and instigating the next construction information evolution are discussed.

Keywords: construction automation; construction management; Hong Kong; integration; PIM

Integrating software and hardware to enhance classroom BIM instruction

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University based construction management programs typically instruct students in the use of Building Information Modeling "BIM." The students' interactions with BIM require them to perform exercises using computer software related to modeling, estimating and scheduling. **Most of the students' BIM interactions are confined to software environments** and do not make connection with the construction environment. Some students may be more focused on the built environment and may be less comfortable behind the computer. They may not as eagerly adopt BIM or see the benefits of using this tool in the field. To bridge this gap, a program has been developed that combines BIM modeling with advanced robotic surveying equipment and unmanned aerial systems (drones).

Auburn University Building Science students complete a project prior to graduation which combines all skills learned throughout the curriculum. Students select different buildings for their project and one requirement is to model the foundation and superstructure of the building from 2d construction drawings. With the 3d model complete, the students learn how to export the necessary data and utilize robotic surveying equipment to outline their foundation in an outdoor grassy area. Photographic data is obtained using a drone, processed, and is then brought back into the BIM model to verify the accuracy of the physical layout. This paper details this program and looks at the software, equipment and techniques used to demonstrate the value of integrating BIM with work performed in the field.

Keywords: BIM, drones, surveying, robotic total station

Volume - forming 3D concrete printing using a variable - diameter square nozzle

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3D Concrete Printing (3DCP) process is rapidly developing worldwide, showing its ability to construct large-scale components or even a building. However, the current 3DCP process has found it hard to manufacture architectural components with detailed ornamentations and features on their surface due to the Fused Deposition Modelling (FDM) manner that generates fixed-width thick filaments. This paper introduces a novel Volume - Forming 3D Concrete Printing (VF3DCP) method applying a variable-diameter square nozzle to manufacture architectural ornaments. The VF3DCP method directly fabricates a variable cross-section volume during one-time work instead of an FDM accumulation process. A VF3DCP extrusion kit prototype containing a steering module and a nozzle-varying module and a particular adaptive tool path planning algorithm are developed. Functional relationships of four key process parameters for a trial material, including nozzle diameter, nozzle moving velocity, material extrusion rate and tool path curvature radius, are fitted by process tests. Finally, a case study into a VF3DCP architectural carve pattern is conducted, which shows the potential of the proposed method in manufacturing architectural ornaments.

Keywords: concrete printing; volume forming; variable nozzle; architectural ornament

Artificial intelligence assisted professional work in BIM: A machine reasoning extension

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A rule based semantic method is utilised as a model and is demonstrated to tackle the problems of analytical processes. The investigation of BIM-based cost estimation confirmed that industry foundation classes (IFC) can provide construction project semantics but incapable of relating domain semantics and pragmatics. Our model provided the rules that three components are necessary to gain a full awareness of the domain which is being computerised; the information type which is to be assessed for compatibility (syntax), the definition for the pricing domain (semantics), and the precise implantation environment for the standards being considered (pragmatics). This paper outlines the way in which the proposed approach has been verified, by employing a selection of codes created by the prototype of the data based model. The standards of practice which have been established are then verified, in accordance with the actual building information gained from IFC. The utilisation of this approach has significantly advanced the procedure of automating professional costing practice within BIM. These justified outcomes demonstrate that, by implementing this model, the reasoning ability can be used by the BIM context and the restrictions around the application of BIM will be reduced. The BIM platform is directly affected by the IFC file that is housed within the ontological structure which has similarities to the Semantic Web and Logic Programming. The adoption of this methodology has greatly advanced the process of automating complex sets of construction standard, allowing the automation of analytical processes. It also outlines the possible connection between machine learning and machine reasoning in order to facilitate wider adoption of computer aided professional practice.

Keywords: AI; BIM; ontology; rule-based; semantic



chair: Borja Garcia de Soto

Creative Management

15:00-16:00 Sunday – 1 July 2018

Involving knowledge of construction and facilities management in design through the BIM approach

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The construction industry has increasingly realised the importance of knowledge. Accordingly, various strategies and tools have been applied over the years to support knowledge management (KM). In particular, building information modelling (BIM) is a technology that has recently emerged in the construction industry. BIM is an object-oriented and parametric-based tool with the features of digital visualisation, life cycle simulation, coordination and collaborative environment. Consequently, many studies have been conducted to explore these four aspects. However, existing studies on BIM-based management mainly focus on the information level. By contrast, only a few studies have explored KM under the BIM environment. Therefore, this study explores the potential and expectations of BIM-based KM for the early application of knowledge of construction and facilities management (FM) into the design stage. A total of 30 semi-structured interviews are conducted to collect qualitative information from the AEC industry. The existing KM practice is explored based on the analysis of the collected qualitative information. Thereafter, a discussion is presented on how the BIM-based KM can be used to mitigate the current KM challenges. Lastly, this study presents the expectations on BIM-based KM for involving the knowledge of construction and FM into the design phase. Overall, this study provides new insights into the transformation of research focus from BIM-based information management to BIM-based KM.

Keywords: Building Information Modelling (BIM); knowledge management; construction project management; collaboration

A study on adjustment method of finishing work schedule based on image detection for high-rise building construction

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As recent buildings have been getting higher and larger, the finishing work management has become a key factor for successful projects. Although many finishing work management techniques have been trying to set up a measureable scheduling plan at early stages before construction lift installation, but schedule adjustments according to site condition and construction progress are inevitable because there are many unexpected variables. To develop the assistance tool for finishing work management techniques such as TACT or LOB (Line of balance), in this study, we suggested image-detection (helmet detection) based labor counting method. The internet protocol cameras at each inside of construction lift cages collect and send photography data to processing server. And through image detection processing using photography data, it is possible to count the number of workers put into each finishing work. The worker count result is used for comparison with the existing finishing work schedule. This study has served as a key lead of lift monitoring based construction process management. Therefore, it is anticipated to settle as a system based data-centric construction management technique in the field.

Keywords: constucrtion lift, finishing work schedule, image detection, helmet detection

Country portfolio model considering market uncertainties in construction industry

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An recent decades, market uncertainties such as unpredicted economic recessions and expansions have significantly affected to the international construction market. These uncertainties arise simultaneously either at the country level or more broadly and traditional project-based risk management has limited to manage a contractor' profit. From the perspective of managing the market uncertainties, therefore, this study proposes country portfolio model that provides an optimized country portfolio solution through considering on the market outlook, country risk and expected profitability. These are evaluated by country-specific data related construction market and actual project performance data using monte-carlo simulation and genetic algorism. It is expected that the proposed country portfolio model will support to decide better decision about entering new international construction market by giving the ideal country portfolio considering market uncertainties.

Keywords: country portfolio; market uncertainty; international constrcution market

Using RFID's for job-site productivity evaluation of labor and crews

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Radio frequency identification (RFID) provide unique identification of objects through non-contact scanning. RFID technology has developed to the point where the price point has made the technology pervasive for inventory control and management of commercial products. Inventory control and storage management is paramount within construction and RFID's provide a useful alternative to bar-codes and other inventory management approaches. RFID's have the additional benefit of providing short-range communication capabilities which could enhance security and theft prevention through 'geofencing' style control. Material and equipment management are natural applications for the technology. The question naturally arises as to the impact of RFID on labor management and how such technology could be used to improve job-site productivity. This has been explored through research performed on-site in the Middle East to track location of workers and to post-process information for productivity assessment. The results of the study will be presented, the advantages and disadvantages discussed, and future research directions proposed.

Keywords: construction; productivity; RFID



chair: Levente Mályusz

Creative Technology and Materials

15:00-16:00 Sunday – 1 July 2018

Initial investigation of generating electricity from concrete

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Cement heat of hydration (HH) can be problematic especially in mass concrete structures as it causes thermal stresses that can lead to failure. Previous and current research has focused on minimizing the HH and mitigating its effects. The methods currently used for treating the HH in mass concreting varies between using: adding supplementary material to concrete, precooling of aggregates and mixing water, post-cooling of concrete, insulation of concrete members, and placement of concrete in thin lifts. These methods result in adding more cost and time to the construction project. This research sheds the light on a new approach in treating the cement HH. The paper presents initial experimentations conducted to dissipate the HH from the body of a concrete structure and convert it to electricity. This research should prove useful in laying the foundation for the development of more sustainable construction methods for mass concreting.

Keywords: heat of hydration; mass concrete; construction methods

Optimizing 3D printing path to minimize the formation of weak bonds

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3D concrete printing has proven to be a highly favorable construction method in terms of time reduction, cost optimization, architectural flexibility, sustainability, energy use, and others. However, the quality of the final product certainly has a priority over all of these attractive features of the technology. Yet research has given little consideration to investigating the structural integrity of 3D printed concrete structures. Research states that printed structures exhibit sufficient strength as compared to traditionally built structures. Nevertheless, the fact that this strength is sensitive to numerous factors including the machine setup, the printing process, existing conditions (ex. Temperature) and others, should be studied. A major determinant of the reliability and quality of printed structures is the adhesion level between subsequent layers. Poorly adhered concrete surfaces result in weak bonds that in turn reduce rupture strength. The time elapsed between printing successive concrete layers should be bounded to ensure that concrete is flowable enough to adhere to previous layers. For a given concrete mixture design, this time is a function of travel distance and speed. Thus, this research aims at finding the optimum printing path that minimizes the formation of weak bonds without compromising buildability for a given structure and a defined speed. The research employs Discrete Event Simulation to model the printing process for numerous possible travel paths and assess their adequacy by comparing travel time to allowable time limits.

Keywords: 3D concrete printing; delay time; DES; path optimization, weak bonds

Variable Refrigerant Flow (VRF) systems in the South-Eastern United States

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This research study endeavored to evaluate the use of VRF systems in the South-Eastern United States. More specifically, to understand and analyze why these systems have not been popular in this part of the world. The VRF technology, invented by the Japanese, has been around for more than 30 years. Europe and Asia-Pacific regions are two biggest consumers of this technology with their combined market share of 65% of the global market. The research aimed to get answers to three basic questions (1) What is the condition of commercial VRF market in the South-Eastern United States? (2) Why have VRF Systems not been popular in the U.S.? and (3) What is the future path for this technology in the U.S.? A survey questionnaire was carefully developed to understand and analyze -What is the extent of penetration of VRF technology; What is the level of awareness about this technology; and what types of projects are being preferred for VRF systems. The results of this survey were evaluated along with other literature including reports from analysts and interviews of leading VRF manufacturers.

Keywords: VRF Systems, HVAC, energy efficient air conditioning systems, refrigerant

A study to investigate using mobile devices in the construction management classroom as rationalized by the needs of industry

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The construction management (CM) curriculum is constantly adjusting to keep pace with changes and developments in industry. Often times, CM programs will make use of an industry advisory committee to make sure that the program remains relevant and is aligned with the needs of industry. Technology is a common subject when faculty and industry professionals converge. At times the path is clear for what needs to be done, and other times no real direction is provided to make sure that universities are doing what is necessary to meet the needs of industry. In this study, a detailed survey was administered to industry professionals with the intent of using this data to inform CM academic programs in terms of what mobile device would be best to use. Eventually, this data will prove useful in helping faculty design course curricula to include the right kind of mobile device for the right type of learning activity.

Keywords: mobile technology; active learning; construction education



chair: Daniel Castro-Lacouture

Automation and Robotics in Construction

15:00-16:00 Sunday – 1 July 2018

Simulating the workflow of robotic steel and concrete 3D printers to build organic shaped structures

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For decades, humans have designed concrete structures according to limited shapes of concrete elements that can be cast into forms and rebar shapes that can be manufactured on a mass scale. Architectural creativity has always been bound by the structural design capabilities and constructability. With generative design emerging, organic shapes of architectural elements are expected to be more emphasized in design outputs. This is accompanied by organic design of structural elements and reinforcement shapes that are generated with optimized layouts based on algorithms that explore thousands of design possibilities. Manufacturing of such steel reinforcement has never been possible before. However, with the emergent of 3D printing and advanced robotics in steel printing, engineering designs are only **bound by the architect's creativity**. **This paper aims to propose, analyze and optimize the workflow of concrete and steel printing robots on a construction project.** Data on the printing properties (concrete and steel printing speed, robot speed, robot arm, etc.) are based on the best performing robots in the industry. Then agent based modelling using Anylogic was performed to simulate the printing of retaining and shear walls for a floor in a reinforced concrete building. Results show values used for later optimization of steel printing heads to concrete printing heads ratios using the current technology. Additionally, this study shows that the proposed method can reduce both time and cost in a construction project and provide cleaner, safer, more automated and unbounded construction processes. Findings from this research call for an in-depth investigation of the capabilities of steel 3D printing and its utilization in construction. It also highlights the importance of considering the application of new construction tools that would cope with the rapid growth of computational power, and its adoption in design practices.

Keywords: 3D printing; concrete 3D printing; steel 3D printing; generative design; robotics in AEC industry

Blockchain in the built environment: analysing current applications and developing an emergent framework

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Distributed ledger technology (DLT), commonly referred to as 'blockchain' and originally invented to create a peer-to-peer digital currency, is rapidly attracting interest in other sectors. The aim in this paper is (1) to investigate the applications of DLT within the built environment, and the challenges and opportunities facing its adoption; and (2) develop a multi-dimensional emergent framework for DLT adoption within the construction sector.

Key areas of DLT applications were found in: smart energy; smart cities and the sharing economy; smart government; smart homes; intelligent transport; Building Information Modelling (BIM) and construction management; and business models and organisational structures. The results showed a significant concentration of DLT research on the operation phase of assets. This is expected given the significant resources and lifespan associated with the operation phase of assets and their social, environmental and economic impact. However, more attention is required to address the current gap at the design and construction phases to ensure that these phases are not treated in isolation from the operational phase.

An emergent framework combining the political, social and technical dimensions was developed. The framework was overlaid with an extensive set of challenges and opportunities. The structured and inter-connected dimensions provided by the framework can be used by field researchers as a point of departure to investigate a range of research questions from political, social or technical perspectives.

Keywords: blockchain; distributed ledger technology, construction industry; built environment; smart contracts

Automation for building performance and maintenance efficiency

Nuno D. Cortiços

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In Western Europe, 80% of buildings will continue to exist beyond 2050. Almost all, 98-99%, need to be updated and maintained in conformity with the requirements to new buildings, designated as nearly zero-energy buildings (nZEBs). In principle, buildings with modern superstructures have a potential lifespan of over 120 years, without compromising safety. Considering materials, labor, logistics, pollution, gas emissions, energy involved in the construction and assuming its heritage value, it is recommended a full modernization of buildings to assure their utility in favor of communities. This research focuses on reaching the maintenance efficiency and buildings performance, without increasing the costs.

The Model is designed to measure and anticipate the degradation of buildings, in three steps. Starting with a network of active sensors, embedded and non-embedded in layers of components and subcomponents, which survey and monitor the condition of the building systems. Those will provide accurate data for computational analysis (first step) and quantify and qualify the viability of construction systems with the highest impact on building performance. The information supports the managers' decisions (second step), before compromising the materials and the constructive solutions, saving work time, reducing maintenance costs, and assuring the highest performance, while preserving user's comfort. And promote a rapid and specific response to stop early anomalies (third step), by obtaining an outsourced contract to respond to daily basis needs (and not tasks) with specialized technicians.

The information collected will help to determine policies, anticipate anomalies, plan proper maintenance, ranking investments and intervene on marked systems. The three-step model aims for a reduction of natural resources usage, a decrease of human impact, to increase the efficiency and to improve the performance of the building stock.

Keywords: autonomous building maintenance; computational maintenance model; facility management; building maintenance sensors; building performance; building user experience; energy efficiency in building

Are computers agents? Considering the implication of classifying computers as occupants on energy consumption and proximity-as-utility equipment scheduling

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Non-ancillary equipment makes significant contribution to building energy demand, consuming as much as half of total energy consumption and three quarters of consumption during inoccupancy. Current proximity-as-utility equipment scheduling does not reflect physical or social complexities of mediating equipment, failing to suitably represent equipment and seemingly incompatible with inoccupancy scheduling. This paper draws comparison between computers and conventional occupants attempting to identify the extent which it is applicable to energy modelling. It concludes with the concession of its lack of relevance in inoccupancy equipment scheduling, though inherently convenient and suggests partial decoupling of agents and non-ancillary equipment during occupancy. Proximity-as-utility is herein defined as equipment scheduling defining utility as a Boolean-state power density necessitating the presence of a proximal agent, accommodating short periods where equipment and agent do not cohabit a discrete space.

Keywords: building simulation; occupant ontology; virtual actors; moral agents



chair: István Hajnal

Creative Management

16:30-17:45 Sunday – 1 July 2018

Identifying factors of risk management for the construction industry

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Delays and cost overruns are recurrent in construction projects. Risk management (RM) has been developed to curtain risks associated with construction projects. However, there is no consensus of what factors should constitute RM for construction projects. Therefore, this paper scrutinises preceding studies on the theme of RM and establish core risk management factors (RMFs) that are indispensable to make the concept valuable in the construction industry (CI). A literature search related to RM was conducted in order to identify common RMF. It was indicated that there is still misunderstanding and disagreement over the factors that should constitute RM in construction. However, the RMFs of organisational environment, defining objectives, resource requirement, risk measurement, risk identification, risk assessment, risk response and action planning, communication, monitoring, review and continuous improvement dominate the literature. Identifying RMF that can effortlessly be understood and implemented will contribute to ameliorating the current RM status and boosting the body of knowledge.

Keywords: contraction; factors; model; risk management effectiveness

Attributes of farmers' willingness in participatory irrigation infrastructure management

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Pakistan is agro-based economy. Agriculture in Pakistan relies upon a vast network of canals that is said to be the world's largest contiguous irrigation system. However, over a period of time, the system is deteriorating and becoming hard for the government to coup up with its financial costs. This has led the government to decentralize the irrigation network by means of introducing participation based development programs in various regions to transfer canal ownership to the farm owners. Participation based development has been advocated for its potential to achieve community level success, and to empower the end-users. Participatory development approach has also proven to reduce the burden over public funds. Nevertheless, previous studies have shown that the willingness of the members (i.e., end users) to be the part of a participatory development program plays a vital role in securing success. Following this notion, this study attempts to understand the attributes of farmers' willingness in a provincial level participatory development program. This study identifies that 'willingness' of a farmer to participate is a dynamic process that extends far beyond farmers' mere agreement to the norms of project, but it further requires continued support and action throughout the project life. As a matter of fact, the willingness of farmers' depends upon a range of factors that are further influenced by cultural and geopolitical contexts. This research presents an abstract model indicating factors attributing farmer's willingness in pre-project commencement and during project execution. Unstructured interviews and a questionnaire survey are used to identify attributing factors and to develop willingness model. This paper concludes with a discussion over the role of willingness in achieving targets in case study project. This study will help academicians, researchers and policy makers with better understanding of the role of farmers' willingness in participatory development approach programs.

Keywords: participatory development; willingness; irrigation; infrastructure management

Measuring project risk management performance: a preliminary model

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The function of project risk management (PRM) is to understand the uncertainty that surrounds a project and to identify the potential threats that can affect it as well as to know how to handle these risks in an appropriate way. Then, the measuring of the performance of PRM becomes an important concern, an issue not addressed yet in the research literature. It is necessary to know how successful is the application of the PRM process, and how capable is the process within the organization. Regarding construction projects, it is essential to know if the selected responses to mitigate or eliminate identified risks were suitable and well implemented. This paper presents a critical analysis of the relevance of measuring the performance of PRM and the benefits of doing so. Additionally, it presents a preliminary and pioneering methodology to measure the performance of PRM through the evaluation of the adequacy of the responses applied to mitigate risks, as well as to evaluate the resulting impacts as indicators of the effectiveness of these actions. This knowledge will allow construction companies to incorporate good practices, generate lessons learned, and thereby promote a continuous improvement of the whole PRM process.

Keywords: performance; measurement; risk management; projects; key performance indicators

Opportunities for UAV's in construction planning, performance and contract close-out

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Quadcopter drones and other unmanned autonomous vehicles (UAV's) have become common-place and their use is widespread among consumers and professionals in numerous industries. Aerial imagery and video can provide useful perspectives and have great value in communicating progress, for use in documentation of site activity and for use in marketing services. Drones, either through imagery or LIDAR, can further provide quick and accurate surveying information, which is valuable for positioning of facilities and activities. LIDAR data can also be used effectively for quality control and for quantity measurement. Imagery also has further applications in safety evaluation, productivity improvement, security and real-time job-site monitoring. Such additional uses have the potential for making a real impact on successful project delivery while increasing and competitiveness. Progressive construction companies and service providers throughout the globe recognize this potential and see significant promise for tangible return on investment. **This paper will evaluate these opportunities for quadcopters and other UAV's based on experiences of the authors in using drones in Dubai and in the United States. The examination concludes with evaluation of the opportunities and avenues for research using UAV's.**

Keywords: drones; uav's; construction; technology

Correlation between contract type selection and cost growth in U.S Army corps construction Projects

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In United States federal construction projects, government contract managers seek to negotiate a contract type that will result in a reasonable level of contractor risk, as well as provide the contractor the greatest incentive for improved performance. The Federal Acquisition Regulation provides government contract managers a variety of contract types to choose from to provide flexibility in acquiring a wide range of required supplies and services. Contract types can be broadly group into two categories: fixed price and cost-reimbursement contracts. The aim of this research was to investigate the impact of contract type selection on cost growth in USACE construction projects. Based on the quantitative and qualitative analysis conducted, contract type selection does have an impact on construction cost growth. In addition, it can be concluded that negotiated non-competitive task orders and more specifically, those, which use RSMeans and a contractor coefficient, are best at reducing construction cost growth in federal construction projects.

Keywords: cost growth, time growth, contract type, federal aquisitoiin regulation



chair: John Smallwood

Sustanaible Construction

16:30-17:45 Sunday – 1 July 2018

Methodology for assessing the comfort of an urban environment in terms of availability analyzing

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Creating a safe and comfortable environment, developing a human, is a priority of urban development. One of the important stages of the solution to such a problem is the actualization of the regulatory base in the field of city-building, which should lay the principles of a city, developing a human and promoting better health.

The work shows the feasibility for quantitative analysis of safety and comfortable spatial environment when creating general plans of cities and their territorial entities. So, using the method of calculating the integral index of spatial-temporal accessibility of objects that implement the functions of the city, we suggest performing a comprehensive quantitative evaluation of planning decisions in terms of placing of socially significant objects. A key prerequisite for the calculation of this index was the inclusion of the time parameter provided to a person to realize his/her rational needs. This approach is based on the principles of creating biosphere compatible cities that develop a person, and allows not only more fully appreciate the quality of urban planning decisions, but also to consider the interests of groups with different mobility.

As an example, we determined the level of implementation of the city functions **"Knowledge"** (components - pre-school and general education) and **"Entertainment and leisure"** (component – recreation open urban green spaces) for different groups in a new micro-district in Orel. The calculation of the indicator was carried out for children aged 3-4 years, 7-8 years, healthy young people, people in old age and residents with disorders of the musculoskeletal system. For the latter, the obtained values differ from the maximum possible. The analysis noted the insufficient capacity of educational institutions, reflecting a defective personal availability.

Keywords: aged people, built environment, open space, people with disabilities, urban planning

Feasibility and practicality of replacing hydroelectric dams with wind turbines

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There is opposition to hydroelectric dams in the Pacific Northwest as they have come to be perceived as damaging to the environment. Of particular concern are the four dams on the Lower Snake River and their detrimental effects to salmon and steelhead spawning habitats. In the last couple of decades, as climate change has come front and center as a global concern, renewable generation methods have become increasingly important. Thousands of megawatts of wind energy have been installed in the Pacific Northwest. With this new influx of generation capacity there is a renewed push to remove the dams, following the logic that the dams can be replaced by wind energy. This research explores whether this is feasible and examines some of the controversies surrounding hydro vs. wind, and also the utility, environmental and economic impacts of each energy generation method.

Keywords: wind; energy; hydroelectricity; environment; turbines

Development of the prediction model of workers with fatal accident at construction site using machine learning

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In the Republic of Korea, the industrial accident rate and the number of casualties in the construction industry have continued to increase for six years from 2011. The average industrial accident rate is 26.44% and the average number of casualties is 24,183. To prevent accidents, the Ministry of Employment and Labor (MOEL) presents various analysis data through the annual industrial accident report, but this has not been effective in reducing accidents as a result. In this paper, using the Logistic regression model that is one of the Machine learning method, this study develops a construction accident prediction model by training 80% of the data of accident casualties (25,114 persons) and accident deaths (499 persons) by 2016 and tests the predicted model with 20% unused data. And then, this study presents a construction site safety management process using the predicted model. The model and process developed in this paper are expected to contribute to the safety management of the construction site as a tool to prevent fatal accidents of construction workers.

Keywords: demographic characteristics, machine learning, public data, safety management, prediction of fatal accident

Designing city installations for socially and environmentally responsible behavior

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As a result of global climate change, financial crisis, and the public perception of massive overconsumption, designers are increasingly motivated “to do good for society”. In this paper, city installations are considered as good opportunities to connect with public and raise their awareness to sustainability. This is while responsible design and sustainability rarely are the focal points of designing street furniture. The conventional goal of sustainable design initially was to design products that require the least energy to be produced and used and that could be recycled. Currently, the idea of sustainable design is growing to have some type of a higher calling, which may be social responsibility and a public design. This becomes more important in developing countries like Iran, which sustainable issues are still not a public concern.

This paper presents a design case study at Art university of Isfahan, Iran, which explores how designers and design educators can set their own holistic approach to sustainability in new product development, place social awareness, responsibility and behavior in perspective. The experiment consists of practices for designing city installations which are not neutral but a deliberate means to promote different levels of sustainability. The proposed design interventions through the conducted experiment are presented and analyzed with their level of success for implementing different levels of sustainable design from eco-design, to raise public awareness of sustainability, sensate or educate people, and cause sustainable behavior through one of the design strategies of coercive, decisive, persuasive, or seductive.

Keywords: city installations, responsible design, environmentally aware, sustainable behavior

Behavioral and parametric effects on energy consumption through BIM, BEM, and ABM

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Over the past years, several tools and methods have been developed to address performance-related designs and provide designers with integrative platforms to estimate building energy consumption and mitigate its impact. However, the predictions obtained through different energy modeling engines have been typically deviating from the actual energy consumption. As such, many efforts have attempted at bridging this so-called “performance gap. Nonetheless, this was conducted in a fragmented fashion whereby synchronizing the geometric exchange of Building Information Modeling (BIM) to Building Energy Modeling (BEM) was done independently from incorporating, through Agent-Based Modelling (ABM), building occupants’ behavior vis-à-vis energy consumption. Therefore, this paper merges the aforementioned approaches and presents work targeted at assessing the diverse and dynamic energy-use behavior of occupants using BIM, BEM and ABM. To that end, a simulation environment was developed to study both the parametric design and behavioural factors. The design parameters included within a BIM model were utilized to set the thermal zone, the internal zone gains were defined using ABM, and resulting data was exported as an input data file to EnergyPlus. Several experiments have been conducted for the case of an academic office and results of the energy analysis highlighted a variation of up to 11% as compared to static occupant behavioral patterns generally adopted.

Keywords: ABM; BIM; BEM; energy; simulation



chair: Miklóš Hajdu

Visualization, BIM

16:30-17:45 Sunday – 1 July 2018

Quantitative ways of measuring client's preferences: a step toward creating an intelligent architectural design agent

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Technology-driven and digital modeling developments are undeniably changing design and construction professions across the architecture, engineering and construction (AEC) industry. Today, it is impossible to conceive of an architectural practice without using computer tools right from initial design conceptualization to the creation of construction drawings for a given project. The computer applications delivered new capabilities to automate the design process and offered various possibilities of assistant to the designer. However, they are not smart enough yet to understand clients or end users' (e.g. building occupants) needs or expectations and innovate a building design. Artificial Intelligence (AI) could be a solution to making architectural and building design process less time-demanding and more organized with minimal manual interference. The ultimate aim of this **study is to make AI part of AEC's digital journey, by making an intelligent agent able to both understand client needs and produce building designs.** An intelligent design agent is defined as an autonomous entity that perceives client needs and makes design decisions towards achieving client satisfaction while balancing design and technical objectives. There are two challenges with respect to creating intelligent design agents; (1) finding **quantitative ways of measuring client's needs and preferences,** and (2) providing a mathematical framework for making design decisions. This study focuses primarily on the **first challenge and proposes a solution for creating measurable data about the client's** needs and preferences. First, an overview of technologies that support quantitative measurement of people's physical, emotional, and behavioral characteristics is presented. These technologies include eye tracking, facial expressions, electrocardiogram (ECG), electroencephalogram (EEG), electromyogram (EMG), and galvanic skin response (GSR). This overview will enable us to understand potential applications of psychological measurement in the AI domain. This will be followed by a hypothetical design experiment **to test the hypothesis that we can determine a subject's degree of satisfaction by recording** and analyzing his or her eye-movements and facial expressions when presented with a collection of visual data, like window design options on a screen. The participants are provided with window design options and asked to evaluate each design based on their preference by giving it a score. While study subjects complete evaluation tasks for each design option, we record their interactions using eye-tracking and an automated facial **expression tool. The objective is to find a relationship between subjects' preferences (as the independent variables) and the emotion expressed and the time spent on each design (as the dependent variables).** This will allow us to provide a first look at how subjects interact with different attributes.

Keywords: eye-tracking; facial expressions; end-user satisfaction, building design

The gradual transition to BIM in Syrian companies

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The successful execution of construction projects, keeping them within estimated cost and the specific schedules primarily depends on the existence of an efficient construction sector capable of sustained growth and development in order to handle with the requirements of social and economic development and to utilize the latest technology in planning and execution. Many studies and researchers discussed the situation of construction in both of developed and developing countries; there is considerable dissatisfaction with the quality, cost and delay of construction, and Syria, not an exception.

The researcher suggested BIM as a tool to improve and innovate the building reality by using a good method to measure the performance of GCEC company in Syria; this method is the: BIM3 (BIM Maturity matrix) which is a tool to identify the current BIM maturity of organization or project team. It does not only give an indicator of the last performance, moreover, it helps the building's company in moving from measurement to management, **and to anticipate needed changes in the organization's strategic, by measuring the current** BIM level in the company through BIM maturity areas (TECHNOLOGY, PROCESS, POLICY) based on capability set v5 and key maturity areas at granularity level1 (initial, defined, managed, integrated, optimized) and putting recommendations for moving to next level. Successful accomplishment of these two tasks represents the foundation of good performance management.

Measurement provides the basis for an organization to assess how well it is progressing towards its predetermined objectives, help to identify areas of strengths and weaknesses and decides on future proposals. Performance measurement is not an end in itself, but a tool for more effective management.

Keywords: BIM; BIM maturity; building; performance; Syria

Identification of relevant project documents to 4D BIM uses for a synchronous collaborative decision support

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Currently, the main use of 4D BIM is for visualization of the planned construction process. However, other uses have not yet been fully integrated into construction practices [1]. This paper presents a review of existing context to envisage ways of fostering the implementation of all 4D uses, and also to propose 4D BIM as a support to the decision-making process. Further the research will be completed by survey responses. In order to fully understand and efficiently implement 4D BIM models and methods, we need to develop a precise knowledge of which digital documents should be used and how they influence the decision-making process. This paper studies the convergence between 4D BIM uses and the project digital documents uses. We hypothesize that a construction simulation visualization of the 4D model is a useful source of information and a support for decision-making during a collaborative session. The visualized information and model development level correspond to the decision-making objectives [2].

Keywords: BIM; 4D BIM; 4D BIM use; AEC project management; collaboration; decision-making

The development of BIM-based augmented reality system for fire safety equipment inspection

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The purpose of fire safety equipment inspection and maintenance is to enable the equipment to start correctly and perform its expected function when fire protection is required to achieve disaster reduction. In the current fire protection maintenance inspection operation stage, the content and methods of inspection stipulated by the regulations are to be followed. Therefore, the relevant file drawings must be consulted before the inspection and maintenance operations are performed. However, because the documents and files are still in paper form, it is difficult to determine and read the information on the inspection and maintenance operations. In addition, it is time-consuming as well as strenuous. To solve the above problems and to help inspectors obtain the information they need as efficiently as possible, this study uses the building information model (BIM) to build the components of fire safety equipment while simultaneously **inputting data related to the components' life cycle into the Revit 3D model using the COBie Toolkit**. The data are further organized into a cloud database to enable augmented reality processes such as visual simulation and the use of mobile devices in future inspections. This eliminates the limitations of paper-based documents. In terms of system development and case verification, this study used augmented reality technology to present visual simulation of the equipment. The selected case studies demonstrate that BIM ensures the integrity, accessibility, and efficacy of data, while the augmented reality technology combines data with physical objects to provide information immediately in a visible and convenient manner. The developed model therefore is an effective tool that efficiently meets the requirements of fire safety equipment maintenance inspections.

Keywords: Augmented Reality (AR); Building Information Model (BIM); Construction-Operations Building information exchange (COBie) ; information exchange; fire safety equipment testing

Application of 4D CAD system for infrastructure projects with construction schedules and distance coordinates

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The typical constraints in expressing the current construction status of railway and road construction projects in a 4D CAD system are the complexity of creating 3D objects for many earthworks and non-repetitive processes. Also, since most of the work is done in a linear pattern in a horizontal work space of several tens of km, there are some parts that are difficult to express by the commercialized 4D CAD system oriented on the building project. In the activity management of the railway construction, most activities such as earthwork, bridge, tunnel, and catenary line except railway station are managed by the distance of linear axis. In other words, a methodology is required in the 4D CAD system to grasp the distance coordinates of the activity in addition to the construction schedule even when 4D objects are implemented. In this paper, the authors propose an automatic transformation method to linear schedule chart of Gantt chart expressed in a 4D CAD system, and propose a methodology for specialized functions of 4D CAD system which converted linear schedule chart and 4D object are interlocked.

Keywords: infrastructure project; linear schedule chart; Gantt chart; 4D CAD



chair: Farzad Pour Rahimian

Creative Management

09:45-10:45 Monday – 2 July 2018

Construction productivity and construction project performance in Indian construction projects

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In order to ensure the performance of a project, it should be defined in terms of some measurable key parameters. Past researchers have identified project performance parameters such as cost, safety, construction productivity, and quality. Amongst all of them, construction productivity is one of the most reliable parameters of project performance. Performance can be measured at various levels including sector, organization, activity and project level in project-based organizations. The methodology adopted to conduct the study is to collect the data through a structured questionnaire survey using convenient sampling technique. The number of variables selected from the literature for the study is 26 and the targeted data collection for the study is 125. The collected data has been analyzed using relative importance index (RII) to priorities the variables on the basis of their relative importance. The findings of the study concludes that the most significant 3 attributes impacting CPP are projected coordination meetings, coordination between all stakeholders, and top management support to PM having a relative value of 0.84, 0.82, and 0.69 respectively. SPSS 21 software tool has been used to check the reliability of the data and to perform factor analysis and the factors are pre-construction management, financial management, socio-economic management, coordination and communication management, resource management, commercial management, site management, and rework explains a variance of 14%, 10.3%, 9.1%, 7.1%, 6.3%, 6%, 5%, and 4.3% respectively.

Keywords: Construction Productivity; Construction Project Performance; Indian Construction Projects; Factors; and Project Management

Trust: Work-related crime in the AEC-industry

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In March 2014, the Norwegian newspaper Aftenposten released the first of 45 articles concerning the shadow economy of the Norwegian construction industry. It provided evidence that criminal actors continuously managed to infiltrate the construction supply chain. Therefore, this paper investigates the following research questions:

1. What are the main challenges regarding work-related crime?
2. How do contractors manage their reputation in the aftermath of work-related crime executed by subcontractors?

This exploratory study started with a literature review. It was followed by a case study based on a document study and 12 semi-structured in-depth interviews with representatives on strategic level. Some particularities of the AEC-industry makes it vulnerable to work-related crime. Complex supply chains, autonomous project managers measured on net profit, high weight on price etc. are examples of characteristics. The literature review reveals a knowledge gap regarding the current state when it comes to crime and crime-prevention within the industry. The findings indicate that the contractors managed the reputational challenges that emerged in the aftermath well on a strategical level. This was accomplished by clearly distancing themselves from the criminal actors within their projects, while still taking responsibility for correcting the situation. In this case study, the client even expressed increased trust in the major contractor after experiencing how the major contractor handled the situation. However such an approach might work the first or second time, but such an approach might work a couple of times, but with repeated infiltration of criminal actors the contractors have to do more than distancing themselves. Future research should focus on how contractors work to prevent work-related crime on the operational level.

Keywords: International construction issues; Work-related crime; Reputation Management; Trust

Design rules to improve efficiency in the steel construction industry

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In steel construction projects, 88% of total decisions impacting cost are made during the design phase. These decisions are made by design professionals, who have neither the knowledge nor the experience of manufacturing operations. In manufacturing engineering, collaboration between designers and manufacturers is well established and formalized through different methods and design rules such as design for manufacturing and assembly (DFMA). These rules provide designers with essential knowledge to reduce the cost and time of manufacturing and assembly of parts during their design, while increasing customer satisfaction

Building Information Modeling (BIM) and TFC Theory (Transformation Flow and Value) provide to the construction industry, tools and processes to improve collaboration between design and manufacturing phases while reducing waste during projects. However, BIM and TFC theory do not formalize collaboration between designers and manufacturers of steel structures. Yet, the lack of collaboration between these two phases causes lot of rework, lot of waste of time and material during projects.

The aim this research is to develop design rules to overcome some of these issues. These rules use the information taken from the BIM model of 1000 steel structures from a steel manufacturer, to reduce the manufacturing time. These information are grouped and classified according to criteria evaluated using a neural network algorithm. In addition, the recent integration of artificial intelligence in construction projects provides industry with methods to draw from previous projects, essential knowledge for better decision-making. The research shows the strong dependence of the manufacturing time of the steel structures on the quantities of complete cuts and weld in full penetration and on the number of beams that do not come in right angles in the connections.

Keywords: Building-Information-Modeling; Design-rules; Neural-network-algorithm; Transformation-Flow-Value

Exploring opportunities in risks of residential construction projects

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Construction industry is known for its high risks due to its complexity and vulnerability to external conditions, such as political, weather, etc., as well as project related risk factors. Even though risks may have positive or negative effects, risks have been traditionally viewed as negative aspects that should be minimized or avoided. Thus, opportunities that are actually exist and can be explored in some risks are overlooked. The current risk management process need to be made more robust and efficient to capture the possible ways of exploiting available opportunities in the risks. This research examined risk factors associated with residential projects in Andhra Pradesh and Telangana states of India from which opportunities can be extracted and further analyzed to identify the risk (opportunity) factors that have high impact on maximizing project value, so that the current risk and opportunity management processes can be made more robust and efficient. Questionnaire survey was conducted to assess the perceptions of project managers or chief engineers of contractor firms on the risk factors that can be transformed into opportunities in the project execution. From the result, it is found out that even though risks are considered holistically, and the perceived importance is high, the actual implementation is not effective because of the traditional threat-oriented view of the risks. In general, the probability of risks in generating opportunity is not considered to be high. However, a few risk factors could generate high benefit to the project. Eleven important opportunity factors out of 40 factors were identified based on the scores of likelihood and impact. These 11 factors were explored in depth by interviewing experts to gain understanding on the influencing aspects that enable the generation of opportunities from the risk factors and the possible benefits of each opportunity factor.

Keywords: contractor; India; opportunity; project success; risk



chair: Ghassan F. Aouad

Creative Technology and Materials

09:45-10.45 Monday – 2 July 2018

Construction methods used for controlling temperature in mass concrete structures

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The hydration of cement can release a substantial amount of heat that can be problematic in mass concrete structure. This heat of hydration (HH) can produce thermal stresses that can crack the concrete and compromise the integrity of the structure leading to its failure. Throughout the years, different methods have been developed in order to mitigate the negative effects of the HH on mass concrete structures. This study presents a comprehensive review of the previous methods documented in the literature that have been utilized in controlling the temperature rise due to the HH in mass concreting. The reviewed methods were divided into two main categories, namely supplementary material and construction methods. This paper focuses on the different methods of construction that are used to control the temperature rise in mass concrete structures. The paper also presents an analysis of these methods using findings from previous studies.

Keywords: heat of hydration; mass concrete; cooling pipes, construction methods

Dry-mix autoclaved lunar concrete from lower-Ti basalt lunar regolith simulant

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To build a permanently inhabited base on the Moon is a vitally important step to developing deep space exploration and lunar colonization. Therefore, indigenous materials become a significant requirement for lunar construction as transporting the construction materials from Earth is extremely expensive. Fortunately, construction materials can be fabricated by utilizing in-situ materials on the Moon. Dry mix autoclaving is a feasible process for lunar construction material manufacture. In this study, the influence of calcareous material ratio, LRS fineness and briquetting pressure on mechanical property was discussed to estimating the most appropriate technological parameter. The strength forming mechanism was expounded by the investigation of hydration products. The result shows that introducing appropriate amount of high-activity calcium materials can improve the strength and promote the generation of target hydration products. Meanwhile, the increasing of LRS fineness resulted in weakening of compressive strength which may ascribe to the decreasing compactness caused by the trapped gas during forming process with finer particles. The increment of briquetting pressure enhanced compressive strength in a certain range. However, it should be implemented after comprehensive consideration of the enhancing effect. This research provides support for preparation of autoclaved lunar construction materials in the near future.

Keywords: Lunar construction; dry-mix autoclaving; lunar regolith simulant; mechanical property; hydration products

Preliminary structural analysis of a conceptual design for a small-scale erectable lunar habitat

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Manned lunar exploration, again, becomes a research focus in recent years, and a number of the leading countries and regions, have announced their own programs. Beyond moon landing, scientists and engineers have started paying more attention on construction techniques for lunar habitation base. This paper introduces a new conceptual structural design of an erectable lunar habitat, using prefabricated building blocks made from the in-situ lunar regolith. The flank wall and foundation of the lunar habitat are fabricated by cubic blocks, among which joggle joint is adopted. Moreover, the roof is erected by arch segments with joggle joint as well and a 2m-thick lunar regolith layer is placed on top to shield the whole structure against the hostile environment. As to the environmental conditions on the Moon (1/6 of the earth gravity, temperature variation of approximate 300K within a lunar day and frequent moonquake), those loads, which would be regarded as irregular on earth, are actually regular for our lunar habitat structure. In order to investigate the behavior of the structure under such extreme loading, a 2D numerical model is established using the finite element software, ABAQUS. In this preliminary study, responses of the habitat structure under static loads of self-weight, overburden pressure, internal air pressure and temperature variation, are simulated. The simulation results give us some requirements on the structural design of this erectable lunar habitat. Several concluding remarks are drawn for both the building block system and the In-Situ Resource Utilization (ISRU) technique of lunar regolith.

Keywords: erectable lunar habitat; conceptual design; finite element; extreme loading; structural analysis

Social housing to nZEB - Portuguese context

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In the 80's and 90's, the various Portuguese Governments set the goal of rehousing the majority of the low-income families without a proper house, through a program to build Social Housing. Municipalities assumed the role and developed the solutions to meet the needs. The necessities defined priorities, efforts were directed to quantity rather than quality: 120,000 apartments distributed by 24,500 buildings, in 25 years. Designed in-house or contracted out with a conventional approach and a limited budget, around 500 euros/m². The construction was outsourced and hasty, due to time constraints.

Although the construction were common, in technology and design solutions, some architectural prizes, National and International, were given to authorial projects. These became symbols of the progressive Portugal Architectural Heritage and of the success of the Portuguese Social Experience, recognized as architectural points of interest, for tourist and specialists.

As time goes by, maintenance falls short and requires critical conservation, tenants demand rehabilitation and renovation, mostly to situations related to the loss of comfort and quality, associated with water damages in the constructive solutions.

The research regarded the latest European Union policies, on GHG emissions and energy consumption reductions in new building design, to pursue the **nZEB's, "nearly Zero Energy Building(s)" concept**. By developing a low-cost building renovation founded on new constructive solutions to actualize the envelopes' response: decreasing maintenance's needs and expenses, increasing user comfort while aiming the reimbursement of the investment period. Based on the **"Renovation or Rehabilitation — Decisive Gains (RoR-DG)," (Nuno D. Cortiços)** benefits were accounted considering achieved savings minus investment: relying on the system's performance, as rated by the key indicators of **"Facilities Maintenance Management Model" (Igal M. Sohet and Sarel Lavy)**. This approach was applied to measure the impact of the first Eco-Neighborhood, applied to a Lisbon social housing park (Bairro da Boavista, Monsanto). Although the **Program's positive** achievements, the results show a low impact on efficiency. For the future actions it is advisable an overall thermal reinforcement, follow-up measures, additional financial support, and the tenants' commitment.

Keywords: social housing; building performance; building maintenance; building renovation; facility management; properties managers



chair: Adel Francis

Creative Management

09:45-10:45 Monday – 2 July 2018

Using historical data of economic variables in investigating variations in building construction cost index

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The construction economy is exceptionally dynamic. Any variation in the prices of raw materials, labor, regulatory costs, and energy can have a major impact in the construction industry and make it difficult to control costs especially in large scale, long term and complex projects. Building Construction Cost Index (BCCI) is used in cost estimation of buildings and is defined as the measure of the changes in the cost of construction input items relative to the average price level of a base year. Therefore, it is important to understand the influencing factors and the impact of input variations in BCCI for limiting potential financial risks in construction projects. This study aims at investigating whether the historical data of different economic variables is useful to figure out the variations in BCCI. Data is obtained from the publications of the Turkish Statistical Institute to understand the relationship between BCCI and three factors including domestic producer price index, consumer price index and construction labor input index. In addition, the strength of the relationship between BCCI and aforementioned factors are analyzed via statistical analyses.

Keywords: Building Construction Cost Index; domestic producer price index; consumer price index; construction labor input index; statistical analyses

Improvement measures for the maintenance market through the current status analysis in Korea

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The construction market in Korea has developed through the quantitative expansion of economic development over the last decades. However, due to recent trends in the decrease in construction volume and shift of paradigm from construction of new facilities to maintenance of old facilities, the number of buildings aged over 30 years in Korea have accelerated rapidly. After the emergence of a construction trade with specialty on facility maintenance and management, policies and regulations related to the roles of a contractor specialized in facility maintenance and management in Korea was created in 1990. However, due to the uncertainty of the scope of work, there still exists conflictive viewpoints among construction stakeholders – mainly the general and specialty contractors – in the market. Furthermore, whilst the number of contractors licensed for facility maintenance and management work is too large compared to its market size, the contract amount per construction project is continuously decreasing. Therefore, this study identifies the problems related to the market structure in the Korean maintenance market. Also, this study suggests improvement measures for the Korean maintenance market and presents a structure for sustainable construction delivery in Korea.

Keywords: facility maintenance and management, maintenance market, institution

Construction scenario for water supply infrastructure in North Korea

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The plan on residential supply in North Korea is needed for stabilization of Korean Peninsula after unification. While infrastructure and building construction are essential parts of this preparation, water-supply infrastructure is to be considered as a first step for establishing a stable residential environment. An arranged database on water resources in North Korea is primarily needed in order to plan for a mass supply on water-supply infrastructure and residential construction. Therefore, this study proposes a database of water resource in North Korea and a construction scenario on water-supply infrastructure. The results of this study are expected to be used as probable data for the construction of water-supply infrastructure in North Korea.

Keywords: water resource; construction scenario; North Korea; Korean peninsula; infrastructure

Qualitative analysis of electrical-related change orders on university projects

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Electrical construction is ubiquitous on building construction projects. Quantitative change order analysis on building construction projects at two American universities showed that electrical change orders were disproportionately high (11-16%) as compared to general contracting (5-10%) or mechanical (5-8%) construction-related change orders, on a percentage of contract value basis. The purpose of the research described herein was to qualitatively analyse electrical change order descriptions on completed building construction projects to discern why this variation exists. The descriptions for 1,214 change orders (associated with 215 projects completed over a seven-year period) were collected and categorized based on the 20 separate reason codes. The reason codes associated with access control/security, interior lighting, circuitry, and low voltage wiring were found to have the highest prevalence. Also, the analysis showed that many electrical change orders were related to work items accounted for by the project team during preconstruction, but not contracted for during the initial tendering stage. Hence, these additional costs, which account for approximately half of the electrical change orders (as a percentage of contract value) were changes to the electrical scope of work as originally contracted, but not changes to the project itself. The results of this analysis show the value of qualitatively tracking (through codes or other methods) change orders, as opposed to purely tracking costs.

Keywords: change orders; public construction; electrical construction



chair: **Zoltán Sebestyén**

Creative Management

11:15-12:30 Monday – 2 July 2018

Product service systems in construction supply chains

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The shipbuilding, automotive and aerospace industries are examples of industries offering product service systems (PSS) to their customers, i.e. they combine physical products with services to add increased value. While product service systems are well established in many manufacturing industries, it has barely emerged in construction, which is mainly explained by the well-established project-based organisation of construction work. Thus, implementation of product and service systems in construction will challenge the established utilisation of technical solutions and systems, production processes and supply chains. The objective of this study is to identify and critically review examples of product service systems in construction supply chains, with the purpose of describing how it challenges prevailing business systems and organisation of construction work. The study rests upon empirical data collected in two case studies at Gyproc Saint-Gobain in Denmark and Celsa Steel Service in Sweden. The two case studies reveal significant challenges related to the implementation and marketing processes of product service systems. Companies that develop and expand their business offers by providing new product service systems find themselves operating in two parallel market segments, i.e. the traditional market of construction components and the new market of product service systems. The product service systems reviewed in the two case studies show a strong focus and emphasis on the development of the offer and the operational platform, while the **companies' roles and market positions remain unchanged**. Thus, the case study companies organise and operate their businesses and market relations as before the implementation of the product service system. The conclusion is that development and implementation of product service systems in construction supply chains, even at the low end of product complexity represented by single building components, require awareness in the **companies' offer of products and services, development in operational platforms as well as clear market position**.

Keywords: Product Service System; operational platform; market position; industrialised construction

Organizational culture and stakeholder success criteria in construction projects

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This paper presents the findings of a theoretical investigation into the association between organizational culture and stakeholder management. With an aspect focused on international construction projects, the study explores the relationship between the cultural origin of key stakeholders and the cultural context in which projects are realized. Emphasis is placed on the examination of project outcomes and the factors that influence cultural domain. Secondary data suggests stakeholder management and corporate culture are **critical areas that decide an organization's success. The importance of these areas** will inevitably grow in the future as projects continue to be procured in a global economy. Identifiable theoretical associations between the constructs have been found that provide early evidence that stakeholders and culture influence project life-cycles. Stakeholders—organizations and their representatives—must be informed of the distinct types of cultures and success criteria to ensure they manage them efficiently alongside traditional and long-accepted project variables.

Keywords: critical success factor; construction project; organizational culture; stakeholder management

Effective process of project monitoring and control

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Cost overrun, potential risks and delay are very common in construction projects due to many factors caused by project participants mainly during construction phase. **Effective project monitoring and control is considered one of main factors that contractor's project managers must adopt to track and assess the progress of any construction project.** The objective of the research is to determine why project monitoring and control is important for project progress, and what are the best practical techniques that can be used to monitor and track the work progress for any project, and to identify and make timely recommendations for necessary corrective action in response to any schedule delays. Monitoring and control is directly linked to the project management and construction management process to evaluate the project performance that will help the project manager to determine and decide if the project will be completed and delivered on time without any delay. Monitoring is concerned primarily with the ongoing collection of **information's and reviews them on regular basis.**

The results of the study revealed the necessity of needs that must be focused on internal control process and techniques e.g. contractor selection, construction phase, internal control process, job costing and labor management, part of the results are developing the necessary smart effective project controls before starting the execution stage. In the **conclusion, good internal controls are vital for contractor's project managers through proper effective utilization and adoption to monitoring and control process of construction process including the available techniques that must provide and improve the efficiency of tracking tools.**

Keywords: contractor project manager, control process, monitoring process, planning, risk control

Appraising the utility of Internet-mediated communication for qualitative data collection in built environment research

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Qualitative researchers within the built environment (BE) research community are confronted with data collection challenges. Such challenges have been attributed to the nature of the construction industry which has been described as fraught with high worker turnover rates and tight schedule of project stakeholders. These features diminish a **researcher's chances of engaging in successful and in-expensive** data collection exercises. A cursory look at studies reveals the fixation of qualitative researchers within the BE discipline on conventional qualitative data collection techniques whilst neglecting internet-mediated communication (IMC) techniques. This study contributes towards elucidating the usefulness of IMC techniques as a data collection approach for qualitative researchers in the built environment domain. An asynchronous online discussion forum (AODF) case study is deployed as an exemplar in this study. Advantages of ADOF highlighted in the reviewed include: its cost-effectiveness, automatic transcription, ability to reach discussants across various geographical contexts, etc. Also, its shortcomings, like the challenge of sustaining thread discussions were observed. In furtherance to this, it was discovered that the attainment of theoretical saturation with the AODF posed a challenge. It is expected that this study will contribute to the emerging discourse on the utility of such IMC techniques in the built environment domain, particularly with the evolving industry 4.0 agenda.

Keywords: asynchronous online discussion forums; built environment; Internet-mediated communication; qualitative research

The impact of view-restriction: a Delphi case study from Budapest

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Based on the international literature, the effect of an existing panoramic view on the Market Value of properties is positive and significant. This value-adding factor varies by location and by type of view. In Central Europe, no such evaluation study has been elaborated until now.

New building construction may restrict the existing panorama; this is the other side of the same phenomenon. View restriction may result in stigmatization, a negative effect on the property. There are two major methodologies to observe the effect – Revealed Preference Method (RPM) and Stated Preference Method (SPM). One SPM approach is Contingent Valuation (CV), wherein wellinformed stakeholders give their opinion about the impact caused by the investigated effect. The CV methodology – using the Delphi approach – was employed to observe the Market Value decrease in the cases of several restricted panorama situations in Budapest. Based on the research, this effect in Budapest is in line with published western results. The result of the study can be used to support real estate developers and architects in their development decisions.

Keywords: market value, panorama, stigmatized property, Delphi method



chair: Adel Francis

Sustainable Construction, Health and Safety

11:15-12:30 Monday – 2 July 2018

Design for sustainability in education

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While the potential for designers to affect positive change is significant and widely acknowledged, this has remained largely untapped both within industry and education. Although some new educational curricula with environmental emphasis have begun to be developed and implemented. But this is barely a beginning and the new generation of designers still needs to be more educated in sustainability. Current design education have been rarely recognized as a relevant factor in the sustainability discourse. Furthermore, the educational practices are mostly related to eco-design strategies (e.g. energy efficiency, dematerialization, longevity, use of recycled materials, recycling). But Design for Sustainability (DfS) goes beyond the eco-design. DfS integrates social, economic, environmental and institutional aspects. Hence, it is necessary to expand the scope of design education and practice beyond style, fashion or limited trends of environmental concerns to include behavioral, social, institutional issues.

Accordingly, an educational experiment is undertaken by the industrial design students of the Art University of Isfahan, Iran which provides a more coherent framework for sustainable design education. Students have the responsibility to not only include eco-design strategies but also establish Design for Sustainability which promote socially responsible behavior among people. The paper contributes to the knowledge and experience on how integration of sustainability issues in regular product design courses can be accomplished the design activity in order to positively and effectively contribute to the radical change required by the transition towards a sustainable society.

Keywords: city installations, design for sustainability, green design, public awareness, sustainable user behavior

Review of collusion and bid rigging detection methods in the construction industry

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Collusion and bid rigging are deplorable practices, forbidden by law. They are harmful to the society and dangerous for a free market economy. Due to the high value of construction industry production and the importance of the time factor, anti-competitive behaviour in that sector can result in losses extremely significant for the national economy. Effective elimination of cartels and bid rigging requires detection, prosecution and successful penalization of cartels. Disrupting already existing cartels and deterring new ones from emerging is efficient only when there is an effective cooperation between the three above mentioned stages. Classification and brief description of numerous existing collusion and bid rigging methods were performed in this paper. As a conclusion, the author presents an idea to combine AI (Artificial Intelligence) and BIM (Building Information Modeling) together as useful tools for early detection of collusion and bid rigging in public tenders.

Keywords: artificial intelligence, artificial neural networks, bid rigging, BIM, collusion, fuzzy logic

Research on regional characteristics and clustering protection of Shanxi historical villages and towns

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Historical villages and towns are considered as cultural phenomena, of which the origin, generation, and development are closely related to historical environment in certain spatial areas. Historical villages and towns show adaptability to historical environment; moreover, historical villages and towns have also enriched various forms of regional history, presenting different characteristics. In this study, historical context of villages was analyzed by considering geographical environment, geopolitics, and defense policies of Shanxi province in China. Central land that supported frontier was identified; moreover, the exchange between silk and iron was encouraged. To compile regional pattern of **"defense and circulation," special types of old villages were identified in Shanxi province, China**. Military-castle-type structures are present along the Great Wall of China. Businessmen's-courtyards-type structures are present in Fenhe Basin; settlement clusters of castles are present in Qinhe Watershed; port-type settlements are present along Yellow River, and mountain-pass type towns and villages are present along Taihang Mountain. Geographic space, humanistic space, and administrative space were taken into consideration. **This study takes a further step to claim "four areas and two lines" as spatial pattern of old villages in Shanxi province of China. Thus, a "clustering" protection framework was developed.**

Keywords: Shanxi historical villages and towns; regional patterns; evolution mechanism; clustering protection

Energetic analysis of complex modernizations of educational buildings

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In this paper, the complex modernizations of existing educational buildings are examined from energetic aspect. A case study based research was conducted between 2010 and 2017 with the involvement of architect student groups. The selected buildings are **architecturally valuable secondary schools in Győr (Hungary) built in 1950-70**. Firstly, the **present conditions of the buildings were recorded in plans and in experts' reports**. Secondly, 18 complex modernization designs were developed on the 6 buildings in order to offer complex solutions to the existing problems. The analyzing and planning processes were done with a holistic approach. The main motive of building modernization is usually to improve energy efficiency, therefore energy performance of buildings were examined on scientific level according to the Hungarian regulations in the second part of the research. Detailed energy calculations were made in the present and modernized conditions of the school buildings based on design proposals. In this way, the effect and efficiency of each modernizing measure could be analyzed revealing the omitted possibilities of the plans. Main conclusion of the evaluation was that the existing buildings could not fulfil the new, stricter energetic requirements if they had been renovated with usual methods. Based on the lessons, a general action plan was formulated with 12 measures in logical order, which can be applicable on any buildings having similar characteristics to the examined ones. In this way, these can be renovated according to the expectations of cost-optimal or nearly-zero-energy buildings, as well. Suitability of the general action plan was tested with energetic calculations on the studied school buildings. The energetic analysis revealed that the suggested general action plan could be effectively applicable to the modernization of existing educational buildings.

Keywords: building renovation; complex modernization; educational buildings; energetic analysis; energy performance of buildings

A framework to evaluate the resilience of hospital networks

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This paper puts forward as framework to evaluate the resilience of hospital networks. Natural and man-made disasters can lead to significant social, economic and socioeconomic losses. Enhancing the resilience of communities in face of disasters can reduce these losses. Resilience is the ability of a system to resist, absorb and eliminate the effects of a hazard and to resume its performance at the desired level at an acceptable time. The resilience of hospital network in a community is among the most critical factors in reducing the losses caused by disasters. However, in many situations, the failure of one or multiple hospitals in a network reduces the overall capacity of the network, forces the movement of patients from one hospital to another, and leads to significant losses. There is need for an appropriate index that can be utilized in order to evaluate and measure the resilience of hospital network and identify the opportunities for enhancing its resilience. In this paper, a hospital network resilience index is presented. A simulation framework is also introduced in order to measure the resilience of hospital network under uncertainties about the magnitude and consequence of hazard, response of various components of hospitals, and the performance of transportation network and lifelines such as electricity network. The proposed framework can be utilized in order to evaluate the impact of lack of hospital network resilience on its capacity to treat the casualties of a disaster, the movement of patients from one hospital to another as a result of inability of a hospital to provide services, and the subsequent losses.

Keywords: hospital network; resilience index; simulation; uncertainty



chair: Miklós Hajdu

Visualization, BIM

11:15-12:30 Monday – 2 July 2018

A review on Internet of Things solutions for enhancing construction equipment fleet productivity

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The construction business is an ever changing industry facing increasingly bigger challenges, complexity and above all fierce competition. Contractors, in particular those managing fleet of construction equipment, have to cut their margins, increase the efficiency of their work force and assets, and control their total cost of ownership (TCO) to ensure an acceptable return on investment (ROI). As such, the business evolved in many ways to be cost-efficient. For instance, construction equipment manufacturers have focused on optimizing engine productivity, hydraulic versatility, and mechanical robustness, among many others. However, recent trends segued into delivering smart **machines capable of reporting and adjusting equipment operators' behavior to achieve a** better on-site fleet performance. This was made possible through the Internet of Things (IoT) and visualization tools by instrumenting construction equipment and devising advanced technological and on-board sensory systems as well as allowing the transfer of relevant information over a shared network within a 3D environment. The objective of this paper is thereby two-fold: (1) shed light on the latest approaches developed from tracking systems, load weighing systems, on-board operator assists to help equipment operators in spatial navigation, and (2) examine current virtual systems used to interactively visualize instrumented fleet of equipment and provide proactive on-site monitoring. The review revealed that there is substantial room for improvement and adoption of new tools targeted at reducing inefficiencies, improving fleet productivity, and producing higher quality results, in less time and with less effort.

Keywords: construction equipment; Internet of Things; virtual systems; operator behavior; tracking; sensing; load weighing

BIM training in construction management educational practices in Croatia and Slovakia

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Building Information Modeling (BIM) is an intelligent 3D model-based process that enhances productivity and management performance of construction projects. For its successful adaptation, education and standardization are one of the prerequisites and key success factors. Even though some countries in the European Union have started to mandate the usage of BIM on all public projects and have developed standards to support such implementation, Croatia and Slovakia have done little to support such initiatives. Furthermore, to support BIM usage, universities need to update their curricula accordingly and thus enable construction engineers the knowledge and skills. This would lead to new BIM competencies. In order to understand the current status quo of the BIM education provided in Croatia and Slovakia, map the reasons of scarce BIM initiatives and propose guidelines for improvements, we surveyed and compared two representative civil engineering faculties which are Faculty of Civil Engineering Košice and Faculty of Civil Engineering Zagreb. The survey investigated Construction Management program on master study and assessed achievement of each BIM learning outcomes. The results show that very little has been done in integration of different knowledge areas towards open BIM approach. This is especially evident in the knowledge areas such as coordination, interoperability and clash detection. Hence, some rare courses which include BIM are being taught independently of each other and could be set to BIM level 1 maturity level. At the end of the paper we provide guidelines for improvement of undergraduate and graduate studies.

Keywords: Building Information Modeling; construction management; Croatia; education; Slovakia

A BIM based approach for optimization of construction and assembly through material selection

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Olugbenga Akinade, Francisco Sierra, Thép Thanh Lam and Ammar Alzaatreh**

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During the design phase of construction projects, professionals seldom consider implications of design choices in terms of the ease with which it can be constructed. This contributes to wastage when chosen design features and materials result in the use of inefficient construction production and assembly methods. In order to bridge this gap, this study provides an approach for incorporating production knowledge and data into Building Information Models (BIM) to support optimization of building designs in terms of the efficiencies associated with their onsite production. A building design assessment system is developed to aid selection of alternative building design elements and materials in a digital prototype before they are actually constructed. The assessment system relies on an index derived from production knowledge or data related to ease of assemble, speed of assemble and the waste associated with the assembly or construction of a building element or material. This paper presents the identification and prioritisation of criteria for the development of the index for optimal selection of building envelope systems. The criteria were reviewed by an expert panel (n=25) who provided weightings of criteria importance through a voting analytic hierarchy process (VAHP). A schema for implementation through the extension of BIM with external assessment index logic is also presented. The practicality of the system as an indicator of the efficiency with which a design can be built or constructed, provides a solution for leveraging production knowledge and data to improve design in terms of its buildability thereby reducing waste associated with inefficient construction and sometimes redesign or late substitution of materials.

Keywords: assembly; efficiency; DFMA; lean construction; building

Developing an interoperability framework for Building Information Models and facilities management systems

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Despite the fact that the value of extending Building Information Modeling (BIM) implementation through the operations and maintenance phase is simply to reduce the operations and maintenance costs associated with inadequate interoperability, facilities management information flow is neither automated nor seamless. Facility managers do not normally use BIM models data, since they claim that BIM models either do not include their information requirements, or contain a huge amount of superfluous data which makes the data exchange process tedious and overwhelming. Construction Operations Building information exchange (COBie) is developed to improve the facility data handover and to support facilities management systems. However, COBie add-in existing applications have their inherent limitation to generate all facilities management required data, particularly spare, resource and job data sheets, in which a manual data entry is still required. Through a series of interviews with industry practitioners, this paper analyses current data exchange practices as well as proposed a conceptual interoperability framework for seamless data exchange between BIM models and facilities management systems. A proposed database information system that automatically generates a rich COBie spreadsheet by linking BIM data models via the Industry Foundation Classes (IFC) model to facilities management information provided by various sources. The proposed framework supplements the existing body of knowledge in facilities management domain by providing a system that facilitates seamless data transfer between BIM and facilities management systems. Facilities management organisations and owners can use this approach to decrease the redundant activity of manual data entry and focus their efforts on productive maintenance activities.

Keywords: BIM, COBie, data exchange, facilities management, interoperability

Development of a BIM-based cyber-physical system for facility management of buildings

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In the wide facility management context, several processes such as operations, maintenance, retrofitting and renovations ensure that buildings comply with the principles of efficiency and cost-effectiveness. Besides ordinary operation, facility management is responsible for renovation of building facilities and long-term improvement of their performances. In such a scenario, the cyber-physical system (CPS) paradigm with holonic architecture, that will be reported in this paper, can successfully advice the operation management of buildings, as well as long-term refurbishment processes. Indeed and in analogy with the manufacturing field, the developed CPS exploits holons self-configuration and self-organization and overall throughput effectiveness (OTE) metrics, in order to detect the best corrective actions towards system improvements. As a consequence, suggestions and lessons learnt from the evaluation of building efficiency are re-directed to the BIM model. Hence, the digital model acts not only as a repository of currently available equipment for operations management, but also as a repository of the history of the diagnoses that supports decision making during maintenance, retrofitting and renovation processes. As a matter of fact, the repeated detection of a specific issue, since not affected by operations management, should be read as an opportunity to act and enhance the capabilities of buildings components. According to this approach, an automatic real-time diagnosis method is tested in a test case consisting of a multi-use and large public building.

Keywords: BIM; building management system; cyber-physical system; facility management; holonic system



chair: **Levente Mályusz**

Creative Management

14:30-15.45 Monday – 2 July 2018

The predicating determinants accessibility of credit small and medium enterprise in the construction industry in South Africa

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This paper focuses on determining the demographic and company profile that predict credit accessibility for small and medium construction enterprises (CSMEs) from banks in South Africa. The significance of CSMEs in the economy has been recognised. However, construction SMEs in many countries, in particular developing countries, are not performing well. One of the factors for poor performance is lack of credit accessibility to fund SMEs operations and expansion. Even those who get access to credit do not get adequate credit they applied for. A quantitative philosophy of research was adopted which is positivism approach. Hence, data was collected using, questionnaire survey from 179 CSMEs who were conveniently sampled. The questionnaire was developed from extant literature review. The demographic and company profile determinants predicting credit accessibility were identified and modelled with full credit accessibility and credit accessibility to the SMEs irrespective of the amount obtained. The data was analysed using statistical package for the social sciences (SPSS) version 22. Binary logistic regression analysis was used to analyse the predictors of credit from the banks. The results revealed that the credit accessed irrespective of the amount and those who did not receive credit when modelled with the predictors suggested not significant predictors. However, when the predictors were modelled with full and partial credit the results established that, age group, current position in the organization, tax number and location were good predictors of partial credit. The gender of the respondent, type of business ownership and collateral (security) did not predict full credit being obtained. The study cannot be generalised across South Africa because the study was only conducted in the Gauteng province. The value of this study informs CSMEs owners and managers in the construction industry to provide, their age, current position in the organization when applying for credit. Furthermore, they should provide the tax number and the location of the business in order for them to improve their chances of obtain full credit from banks.

Keywords: credit accessibility, determinants of credit accessibility, full credit, small and medium enterprises

Factors affecting readiness of Thai contractor in approaching ASEAN Economic Community (AEC)

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According to the official establishment of the ASEAN Economic Community (AEC), there will be a free movement of products, services, investment, finance and skilled labor. Construction and related engineering services are one of the important services under the General Agreement on Trade in Services which creates both opportunities and threats to Thai contractors. Therefore, Thai contractors should examine their readiness in order to compete in the free trade market. This study aims to identify factors affecting the readiness of Thai contractors in approaching AEC. **Thai contractor's factors in this study merely focus** on the corporate or company level which can be classified into internal factors and external factors. Internal factors were divided into strategic factors, corporate factors, management factors, psychological factors and technical factors whereas external factors were divided into laws and regulations, AEC agreement and socio-economic issues. A research survey was conducted with a structured questionnaire. The target group was 237 contractors whose experience was in both local and ASEAN construction markets. Sample size was allocated by Taro Yamane theory of 95% reliability and the number of samples was 149. The collected data was analyzed by using descriptive and inferential statistics. Findings indicated that the relationship between internal and external factors was positive and was **in the same direction. Internal factors affect Thai contractors' readiness more than external factors. The internal affecting factors of Thai contractors' readiness were technical factors**, corporate factors, strategic factors, management factors, and psychological factors respectively. Meanwhile external affecting factors were socio-economic factors, laws and regulations, and AEC agreement respectively. Focused on the level of affecting factors, the highest was the technical factors which comprised research and development (R&D), information technology (IT) and construction technology. Those affecting factors were mostly located at the organizational level. Therefore, strategic policy and planning should be initiated for those Thai contractors who need to play their roles in the ASEAN construction market.

Keywords: ASEAN Economic Community (AEC); affecting factors; readiness; Thai contractors

The integrated collaborative environment and its value to the procurement process in the Kingdom of Saudi Arabia

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The high level of uncertainty in the delivery of construction projects in the Kingdom of Saudi Arabia, is due to lack of understanding of client requirements and needs. The current collaborative working environment between clients and the contractors needs to be strengthened in order to address this and provide an integrated collaborative environment that is required to improve the procurement processes to add value to the project delivery. This study was undertaken in the lens of interpretivist paradigm. Also, this research presents a comprehensive review of prior studies and suggests a direction for the study in Saudi Arabia. Many studies propose that collaborative work can produce more successful project management of construction projects in many contexts, but this is still a quite under researched topic in Saudi Arabia. The results reveal that the current collaborative way of working is not sufficient to support an effective procurement process. Misunderstanding of this collaborative work working resulted in confusion of applying an integrated collaborative environment in Saudi construction industry. By using integrated collaborative environment both the client and the contractor can enhance those decisions which positively impact the project life cycle. Furthermore, problem solving is important in **assisting the understanding of the role of team members' cooperation to achieve the intended goal of the procurement process.**

Keywords: clients, collaborative culture, construction, procurement process, Saudi construction, industry

Analysis of improvisation in construction through agent-based modelling

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Improvisation is rational and decisive, deterministic and emergent, but impulsive and fuzzy. While the results of improvisation are perfectly understandable after the fact, the decision process is spontaneous in its making. Improvisational practices continue to exist within numerous construction operations where unforeseen uncertainty cannot be fully avoided. Therefore, a construction project will greatly benefit from applying an adaptive planning system that employs improvisation and hence reacts rapidly and wisely in case of unplanned or newly emerging problems. This study aims at developing a simulation model that depicts the improvisation process at the level of planners associated with different construction trades and identify different influencing factors. First, after attaining a thorough understanding of the process based on previous research studies, agent-based modelling is used to model the improvisation process that occurs at the level of each agent (planner), as well as the interaction processes that arise between the agents and the environment (construction project), and among the agents themselves. The simulation model takes into consideration several types of parameters that highly influence how each planner improvises. These parameters are planner-related, project-related, as well as problem-related. The contribution of this study lies in developing a better understanding of the improvisation mechanism within construction as well as identifying the impact of various types of influencing factors on the overall improvisation performance. Future research is recommended to better enhance the practices of improvisation for different construction projects.

Keywords: improvisation; construction; agent; planners

A model to approach BIM adoption process and possible BIM implementation failures

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Adoption of Building Information Modelling (BIM) has increased significantly over the last few years. In France, the level of BIM adoption is measured as quite low compared to other countries. Many guides, protocols and mandates have been produced by governmental bodies and industry associations around the world to facilitate BIM adoption but it mainly focus on technical requirements or describe good practices. This paper is part of a research project that aims to facilitate BIM implementation for design firms by providing an implementation guide or method. This method would be organization-centered (based on the specificities of the company) with more organizational and managerial than technical considerations. Connecting BIM Adoption-Implementation literature with change management (a domain that provides models and strategies to analyze and conduct change) carries an interesting research potential that is insufficiently investigated. The objective of this article is to have a relatively comprehensive view of the factors that can influence the success or failure of BIM adoption, especially at the implementation phase.

Keywords: BIM; AEC; AECO; architecture firms; adoption; diffusion; implementation; implementation failure; adoption drivers; implementation drivers; adoption decision factors; adoption failure; implementation failure; change management; change; risk management; literature review; conceptual model; guide; method



chair: **Miklós Hajdu**

Sustainable Construction, Health and Safety

14:30-15:45 Monday – 2 July 2018

Developing of evolution analysis algorithms in regenerative design and decision-making; demonstrated through a case study in Shiraz, Iran

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Over the last decade the concept of 'Regenerative Design and Decision-Making' has been introduced as a mind-set which considers the integration of all humans' activities and natural systems, in a broader vision than the classic concept of 'Sustainability' (mostly focused on the present). This vision identifies a greater scope, considering 'Regenerative' as a package of 'sustainable for today', 'sustainable for future', and 'heal the past'. The 'system evolutions' and uncertainty of changes, are key factor to be considered in designing of required infrastructures of sustainability for future and healing the damages to the economy, society and environment in the past. this in turn, highlights the role of 'Evolution Analysis (EA)' and 'Future Identification (FI)' in regenerative developments.

A practical solution for FI is to develop EA algorithms, to be applied to identify the rates of changes over the integrating flows, through projects' time-frames in a more precise way. This in turn, saves huge rates of resources through design and implementation of extra infrastructures, to deal with future changes; as well as supporting the decision-makers to reach more realistic solutions, with higher levels of precision.

This paper focuses on a real case-study, the Faculty of Art and Architecture campus, in Shiraz University, Shiraz, Iran, as a part of an evolution analysis research project, sponsored by 'Iran's National Elites Foundation', and the solutions to deal with the real-projects' limitations, such as disorganisation/lack of History Data (HD), stored by different teams over a ten-year period of the campus history. Such limitations, are principally caused by 'changes in management systems', as a key integrating flow in systems' lives, and cause of uncertainties in FI.

Indeed, the paper demonstrates some critical and practical solutions, to develop EA algorithms for Regenerative Design and Decision-Making in real practices.

Keywords: Evolution analysis algorithms, future identification, history data, management strategy change, regenerative design and decision-making

Heritage Building Information Modelling (HBIM) to make informed decisions when retrofitting. A case study

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No-fines concrete (NFC) dwellings is a very common type of housing in the British urban landscape and other parts of the world. However, the fabric of these buildings can not be considered efficient anymore. Therefore, city councils and individuals aim to improve their energy efficiency. Unfortunately, accurate information about the thermal efficiency of this type of buildings is not available, as it happens with many other types of existing buildings. This work forms part of a British Council-funded Institutional Links project to create a Heritage Building Information Modeling (HBIM) web-portal to share key information about heritage building typologies. This paper presents the case study of NFC buildings.

For this purpose, three NFC dwellings (C1, C2, and C3) were monitored, gathering in-situ key information about the thermal performance of the fabric to create a HBIM model where to display the information. It was found that the original $U_{NFC} = 0.85 (\pm 0.052) \text{ W/m}^2\text{K}$, could be reduced to $0.22 (\pm 0.013) \text{ W/m}^2\text{K}$ if 110mm of external wall insulation (EWI) was added. It was also found that the initial in-situ U-value ($0.85 \text{ W/m}^2\text{K}$) was 50% lower than those assumed ($1.71 \text{ W/m}^2\text{K}$). Based on these outputs, two Building Energy Models (BEM) were created and compared, using SAP. One included the traditional assumptions and the other model the actual in-situ data. Higher starting U-values resulted in predicting an unrealistic 27% heating consumption reduction in comparison to the actual 15.5% reduction if the in-situ measured thermal baseline was used.

In conclusion, the use of assumptions for the fabric of a building lead to inaccurate predictions, a performance gap will appear and expectations will be jeopardised. Only the use of actual data can help make optimal decisions. Therefore, the HBIM models will help future stakeholders to make informed decisions based on actual data when trying to improve the thermal performance of NFC buildings.

Keywords: Building Performance Evaluation; No-fines concrete; retrofitting; external wall insulation; heating energy consumption

Preventing the collapse of Reinforced Concrete (RC) structures, and support work during construction: a support work manufacturer's perceptions

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

The study reported on is based upon findings resulting from a self-administered survey of **a temporary works designer and suppliers' staff that attended a workshop presented by the author.**

The salient findings are as follows. 83.3% of the 55 factors are between near major to major / major importance, and 16.7% are between important to near major / near major importance relative to preventing the collapse of RC structures during construction. 83.3% of the 30 factors are between near major to major / major importance, and 16.7% are between important to near major / near major importance relative to optimum support work and formwork and the integrity of structures under construction.

Recommendations include that conformance to requirements is the key, that such requirements 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; support work; zero

Designing for construction ergonomics in Slovenia

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Relative to other industries worldwide, the construction process generates a disproportionate number of fatalities, injuries, and disease, and both the direct and indirect costs contribute to the cumulative cost of construction.

Designers influence construction ergonomics directly and indirectly. The direct influence is because of design, details and method of fixing, and depending upon the type of procurement system, supervisory and administrative interventions. The indirect influence is because of the type of procurement system used, pre-qualification, project duration, partnering, and the facilitating of pre-planning.

The purpose of the paper is to present the results of a study conducted among designers in Slovenia using a self-administered questionnaire, to determine their perceptions and practices relative to construction ergonomics. Descriptive statistics in the form of frequencies and a measure of central tendency were computed from the collected data.

The following constitute the salient findings. Cost, quality, and time are more important to designers than construction ergonomics and project health and safety (H&S). Ergonomics during the construction, and design phases are more important to designers than the other phases. A range of design related aspects impact on construction ergonomics. To a degree, construction ergonomics is considered on most design, procurement, and construction occasions by designers. Practice **notes predominate in terms of how designers' ergonomics** knowledge was acquired. A range of aspects have the potential to contribute to an improvement in knowledge, and the application of construction ergonomics.

The paper concludes that designers contribute to construction ergonomics, but that there is potential for and a clear need for enhanced contributions. Recommendations include the **inclusion of construction ergonomics in designers' tertiary education, and continuing professional development (CPD), to remedy shortcomings in practitioners' knowledge.**

Keywords: construction; designers; ergonomics

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 a 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 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 curve; earthquakes



chair: István Hajnal

Creative Management

14:30-15:45 Monday – 2 July 2018

Practical application challenges for construction submittals in a paperless contract file

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This research study explored the transition from a paper to paperless environment for the U.S. Army Corps of Engineers construction submittal process. For several years, the Corps has intended to implement a new multifaceted version of Common Access Card (CAC) enabled Resident Management System (RMS) to include submittal management. The purpose of this study was to provide guidance to make an effective transition from existing paper review process to a paperless digital paradigm, while securely and effectively incorporating multiple requirements and constraints with multiple users. More specifically, how to process digital submittals uniformly and effectively within RMS provided the viability of RMS version 3.0. The implementation of RMS 3.0 would standardize the electronic submittal process, but has had several years of delay. Current policy for electronic submittals is at the discretion of the Contracting Officer. If approved by the Contracting Officer as an option, electronic submittals may be used and referenced in the contract, but no guidance on how the submittals were processed, which promoted inconsistency. This research used PDT (project delivery team) focus groups in order to uncover the challenges and obstacles of using paperless submittals on USACE projects. Recommendations and future research are also addressed in this paper.

Keywords: submittal, paperless, RMS, Resident Management System, USACE, construction, shop drawing

Collaboration strategy for ODA project using social network analysis

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Recently, Official Development Assistance (ODA) projects are increasing. Since ODA projects are financially stable, engineering companies planning to enter the international construction market need to make ODA projects as a first step. Engineering ODA project evaluates bidders by Quality Cost Based Selection (QCBS) method. Under the QCBS, companies make up for their lack of capacity through collaboration. Therefore, collaboration network information is required for winning. In this study, Social Network Analysis (SNA) is performed using the bidding information of socialbase, road, and water sector provided by World Bank (WB) for Vietnam ODA projects. The objectives of this study is to identify the network characteristics of the three sectors with the network shape and the density calculated through SNA, and to identify the main player by degree centrality and betweenness centrality, and to suggest an appropriate strategy. This is helpful information for decision makers when deciding whether to go overseas or not.

Keywords: Collaboration Strategy; International Engineering Project; Official Development Assistance (ODA); Social Network Analysis (SNA)

Leadership development in the South African construction industry

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The construction industry is one of the major industry in South Africa, due to its positive infrastructure impact to the economy. Like any other industry, strong leadership is fundamental for its growth. Moreover, in order to stay competitive, South African construction organizations must find a way to train their project and construction managers to become capable leaders in their specific disciplines. Hence, this study presents findings on how managers can be developed into leaders in the South African construction industry. The data used in this research 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 well-structured questionnaire aimed at 150 projects and construction managers in the South African construction industry. 110 questionnaires were received and data was analysed using Statkon SPSS software, whereby frequencies, MIS and descriptive were attained. Findings revealed that, curricula education and qualification can help develop leaders in the South African construction industry. Followed by leadership training courses, taking responsibility as managers, and accepting new challenges were seen as important, in addition internal motivation, professional and personal development. The study presents a background about the construction industry and the importance of effective leadership in the construction industry for construction management performance.

Keywords: construction leadership; leadership development; South Africa

Comparative analysis of regional construction labor cost variations via panel data modeling: the evidence of Mainland China

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Labour cost estimation, control, and regulations are of great importance to the final success of construction project, and sustainable development of construction industry. Over the recent years, the affordability and availability of construction workforce, underpinned by rich labour resources across the Mainland China, has gradually become the history and exerted ripple effects on the construction manpower recruitment, cost management, and even industry development. However, little research has been found with focus on labour cost fluctuations at regional level in China. This study attempts to explore the major factors affecting regional construction labour cost variations over the past two decades, from 1995 to 2015. Panel data analysis, and time series econometric modelling, is thereby applied to identify critical determinants of construction labour cost fluctuations across three regions of different levels of economic development, i.e. underdeveloped west region, developing **central region, and developed east region, within Mainland China's construction industry.** Empirical results indicate that gross domestic product (GDP), unemployment rate, construction labour productivity, construction technical equipment ratio, and construction profit rate are five key factors determining the variations of unit labour cost in Mainland **China's** construction industry. GDP, construction labour productivity and unemployment rate are three common factors that affect regional construction labour cost; Besides, construction profit rate is found to be another dominant determinant of construction labour cost in west region, while construction technical equipment ratio acts as a significant but negative factor in central and east regions, with incremental effects towards construction unit labour cost from west region to central region, then east region. For the evolving construction market, these principal findings provide valuable insights for construction enterprises to formulate forward-looking market strategies, and for governments to fine tune economic policies.

Keywords: construction labor cost; critical determinant; Mainland China; panel data analysis; regional level

Challenges faced by stakeholders in the road construction projects in the Gauteng province of South Africa

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This study adopted a quantitative approach as the purpose was to investigate the challenges faced by stakeholders in the road construction projects in the Gauteng province of South Africa. This study adopted quantitative research and a well-structured questionnaire was distributed to different construction companies in Gauteng Province, which were registered with various approved councils construction professionals and contractors such as civil engineers, project managers, directors, quantity surveyors, construction managers and resident engineers. The questionnaires were sent via e-mails, some were delivered to the known construction companies by the researcher and some **were distributed during site clarification meetings of contractors and consultant's bidders** on Gauteng Department Roads and Transport tenders. 75 Questionnaires were distributed and 50 came completed and eligible to use. Random sampling method was used to select the respondents in various organizations. Research findings revealed that Community unrest and land proclamation were the highest ranked factors that pose a major challenge in the road construction, time, financial constraints, cash flow, lack of proper planning, resources, delivery of material, plant and equipment, shortage of skilled labourers, lack of equipment, lack of materials, performance guarantees, project duration/period, cost overruns were the major challenges facing the stakeholders in roads construction projects in South Africa. In conclusion, proper planning, communication is vital to overcome the challenges and government at the other hand needs to partner with private companies in terms of transferring skills and upgrading the upcoming contractors by emerging them with sustainable, independent contractors. Therefore, any challenges found in roads construction might be eliminated in the future projects by lesson learned, by planning for the upcoming project properly and also by identifying possibility risk at the early stage of the project.

Keywords: challenges; construction industry; roads, South Africa; stakeholder



chair: Keith Rahn

Creative Management

16:15-17:15 Monday – 2 July 2018

Best Value Procurement – The first experiences from Norway

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Best Value Procurement (BVP) is a method for contractor selection and project management, which seeks to increase project value by emphasizing the competence and expertise of the contractor. Several studies in the US and Netherlands indicate promising results. The method is new to Norway and pilot projects in the construction industry are testing the method. Limited research has been done to explore the experiences of these pilot projects. This study investigates how BVP was implemented in practice and the experiences with the method to develop suggestions for future projects on how BVP should be performed. The research was carried out through a literature study and two Norwegian case studies. A building project and a medium-size infrastructure project in the Norwegian public sector were explored through nine semi-structured, in-depth interviews and document studies. The findings show that the practical use of BVP aligns with the theoretical approach. However, since the method is new in Norway there are some **challenges, such as the contractors' lack of knowledge of and experience with the BVP method**. This may reduce the potential project value. The conclusion is that BVP is an effective and promising method for contractor selection and project management. However, for the success of future projects using the method, project owners may benefit from providing contractors with more knowledge of and experience with BVP. This can be done by training and by being persistent in using BVP in future projects.

Keywords: Best Value Procurement (BVP); Early Contractor Involvement; public procurement; public projects; Norway

Identification factors influencing accessibility of credit for small and medium contractors in the construction industry

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Small and medium enterprises (SMEs) have an important role in the economic development in South Africa. (SMEs) caused competition becomes increasingly fierce. This made construction (SMEs) experiencing more challenge to be able to access credit from financial institution. This paper aims to propose a conceptual framework for credit accessibility among construction SMEs. Several factors are preventing SMEs contractors in accessing credit from financial institutions such as: lack of collateral, high interest rate and bank changes, lack of owner's contribution, lack of good business plan development, lack of excellent managerial skills, lack of business skill and lack of binding building contact agreements. The survey method and self-administered questionnaires were used for data collection. 179 respondents took part in the survey. Data was analysed with binary logistic regression. The results indicate that Age of the firms, ownership structure, company tax number, and location of the business, current position, managerial competencies, and incorporation are significant determinants of credit accessibility for construction SMEs. These findings could be useful to others SMEs sectors in identifying credit approval in credit application from the financial institution in South Africa.

Keywords: credit accessibility, factors influencing, SMEs contractors, South Africa

Analyzing the critical risk factors in oil and gas pipelines projects regarding the perceptions of the stakeholders

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Oil and Gas Pipeline (OGP) projects face a wide range of Risk Factors (RFs) at the design, construction and operational stages of the project particularly because of Third Party Disturbance (TPD) in the insecure environments. The lack of risk information and the root causes of pipelines' failures are hindering the efforts of managing these risks. Therefore, this paper aims to analyze the existing risk factors and recommend an effective Risk Mitigation Methods (RMMs) based on a holistic approach from the prospect of stakeholders' interest. An investigation was carried out to identify the critical RFs and existing RMMs in different circumstances to overcome the problem of the historical records about the RFs and RMMs. The findings of the literature review were used to design a questionnaire survey to analyze RFs and evaluate the "usability and effectiveness" of the RMMs. The RFs were ranked by using Risk Index (RI) method based on the probability and severity levels of each RF. The survey results revealed that sabotage and terrorism as part of TPD, corruption and insecure areas are the most critical RFs, whereas, anti-corrosion efforts, underground pipelines and technologically advanced risk monitoring systems are the most effective RMMs. These ranking are vary based on the occupation of the stakeholder in OGPs; like the planners and the researchers said corruption is the most critical RF, and the researchers said that the advance risk monitoring systems are the most effective RMM.

Keywords: Oil and gas pipelines (OGPs), risk analysis, Stakeholders' perceptions, Risk Mitigation Methods (RMMs)

The relationship of risk assessment with project success: an empirical study of small and medium contractors in Gauteng, South Africa

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Risk assessment (RA) is widely acknowledged to be linked with construction project success (PS). However, there is a lack of empirical evidence to support this perception. Therefore, the current study sought to fill the gap by establishing the relationship of RA with project success. A structured questionnaire was used to collect data from small and medium contractors (SMEs) who were conveniently sampled in Gauteng, South Africa. The data was analysed using the Statistical Package for the Social Sciences (SPSS) version 23, computing inferential statistics. The results revealed a statistically significant relationship between RA and PS; that PS was positively influenced by RA. This was an indication that RA in construction is an important risk management factor that enhance project management decision making and hence influence PS. This finding contributes to the body of knowledge on the subject of RA and management and provide guidance to contractors on the practical implementation of RA concerns for construction PS.

Keywords: contractors; project success; relationship; risk assessment; South Africa



chair: John Smallwood

Visualization, BIM

16:15-17:45 Monday – 2 July 2018

Virtual Reality applications in architecture: Bill of Quantities & Virtual Reality

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As time goes on and building practices change, procedures that at one point seemed indispensable can fall by the wayside. One such example is the bill of quantities (B/Q). Research into recent literature attributes this decline in use to a multitude of reasons such as its complexity and potentially drawn-out time to produce, non-traditional procurement systems growing in popularity and the challenge of using its information in a construction schedule. With these issues in mind, a combined process of BIM, Virtual Reality and including the client in the design process has been proposed as a potential solution. Following a literature review and precedent study, an experiment was carried out using **this new process to simulate a client's design decisions on window and interior furnishings** specifically. Their choices made using Virtual Reality automatically updated a B/Q Revit Schedule and allowed the client to have a firm grasp on the project costs. Not only did this process give the client more confidence in a pleasing final outcome, but the technology ensured an upto-date, accurate and easily understood B/Q. Here lies great potential savings in cost, time and gives the B/Q a newfound importance in future construction processes.

Keywords: Virtual Reality; Bill of Quantities; BIM; Revit

A system framework for RCM-based facility maintenance management in a park area

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There is an increasing number of university campuses and science parks in China. The park areas usually have only one owner, but many organizations, for example, departments and companies, engaged in the facility maintenance management (FMM). These organizations usually are responsible for different disciplines in different facilities independently. Considering the fact that facilities influence each other most of the time, FMM performance for the entire area is thus unwarrantable. Therefore, we proposed a system framework for FMM in a park area based on Reliability-Centered Maintenance (RCM) and the integrated use of Geographic Information System (GIS) and Building Information Modeling (BIM). The requirement analysis was carried out and the system framework was designed. The system framework is valuable for developing software systems that can support multiple FMM organizations in an area to work on the same platform, avoid management problems and achieve better performance. A software system based on the proposed framework is now under construction.

Keywords: FMM; Framework design; RCM; BIM; GIS

A comparison between different approaches for 5D BIM in construction site surveying

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It is well known that BIM technology offers many profitable issues by now. Its benefits are widely experimented and described, especially in terms of design efficiency and interoperability. However, it is not so common, at least in Italy, to see projects completely managed by BIM, especially considering medium and small intervention. This approach should change in the next years while Italian laws will make mandatory, step by step, the use of BIM for public procurement of a certain amount. With the aim of the implementation of BIM in each phase of the project, also in medium and small interventions, the presented research examines the use of 5D-BIM during the execution phase of the process, to assess construction advancements during works with the support of modelling advantages. Then, the research focuses primarily on the definition of proper requirements to outline a 5D site management throughout the whole construction process. After the definition of different needs for the different actors of construction process, the research moved to the possible BIM use for the satisfaction of these needs by the definition of customized parameters dealing with site spaces and facilities, quantities, time and cost management. The study includes also the levels development (LOD) definition of objects aimed to the scope of using information contained in the model for the works advancements checking during the realization of works. An approach was studied to realize the scope of work, tested in different construction sites with the aim to satisfy both the needs of clients, and the needs of a contractor. The considered construction sites are similar in terms of dimensions and amount of works. As will be demonstrated in the paper, the on-field management with the use of models, if correctly developed and used, can **simplify contractors and clients'** inspectors job during the works realization in terms of efficiency of inspection and calculations.

Keywords: 5D; Building information modelling; Construction site inspections; LOD; Medium sites

Should BIM change the language of engineering education?

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Over the last decade the construction industry has been introducing building information models (BIM) as the way to represent buildings and communicate about them. In teaching engineering, we are also creating representations of buildings and communicating knowledge about them. While teaching, we conceptually refer to the very same real world objects that now have an explicit conceptualization in a BIM environment. This explicit conceptualization did not exist in the age of drawings and paper documents.

The question that this paper asks is this: Due to BIM, communication in the industry changed. Should communication of engineering knowledge – teaching – change as well and how?

While much has been written about teaching BIM and incorporating BIM into the curricula, this paper is exploring the general impact of BIM on engineering education. Based on a high-level model of engineering communication, five scenarios of the interplay between BIM-influenced engineering communication and teaching are presented. The paper argues that ignoring BIM may create a cognitive dissonance between study and industrial work. We are finding that the impact of BIM is twofold: vertically there is a need to establish a reference between knowledge concepts (in teaching) and information objects (in information models). Horizontally BIM is an integration technology that allows for a more holistic design and planning. Both the language of individual courses as well as cross **references and synergies among courses should change. A "T" style structure of the courses around BIM is proposed.**

Keywords: engineering education, building information modelling, engineering communication, curriculum development

Mobile-based 3D reconstruction of building environment

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On-time environment perception of construction site is considered as an indispensable step for project management. Real-time tracking and feedback the status of construction facilitate progress monitoring and quality control. Image-based modelling and RGB-D mapping are considered as a non-invasive and low-cost technology which are always used for data collection and reconstruction of as-built building environments. Recently, the arrival of reliable and efficient computational of mobile terminal service has given us an opportunity to develop a mobile-based spatial data reconstruction system. Considering the capacity of processing and real-time performance on a mobile device, Oriented FAST and Rotated BRIEF (ORB) features are extracted. The ORB features are used for subsequent procedures, including tracking, mapping, relocalization and loop closing. In contrast to image-based off-line modelling, a real time Simultaneous Localization and Mapping (SLAM) algorithm was utilized to estimate the camera trajectory while reconstruction the building environment. Keyframes selection strategy was proposed to reduce the redundant images and generate a robust and trackable sparse point clouds. The keyframes and sparse point clouds are transferred to a computer for generating dense point clouds, grid reconstruction and texture synthesis. Finally, the reconstruction result will be transferred back to mobile and can be displayed directly on a mobile device. As an initial effort, this paper investigated the potential of live reconstruction of indoor building scenes on an android mobile device. Taking the advantages of operable and portable, the system can be used for data acquisition of as-built information by construction workers.

Keywords: 3D Reconstruction, As-built Data Acquisition, Mobile Terminal, Monocular SLAM, relocalization

Development of a framework to support the information flow for the management of building

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Inefficient control of information flow in projects is one of the critical aspects that affects the entire lifecycle of buildings. Besides allowing for a simpler and more efficient transfer of information, the dramatic growth of the digitalization process in the AEC industry underlines the need for a common data environment, which manages and shares these data. The increasingly widespread adoption of Building Information Modeling (BIM) is partially leading to a union of multiple levels of information in a single digital model of the building. However, many challenges are still posed in terms of information transfer from the model to operators responsible for keeping building functioning and in good conditions. In fact, technicians could benefit from the immediate availability of data on the current state of buildings and from the level of information detail that can be obtained from digital buildings. The purpose of this work is to create a framework for data management related to the maintenance phase of the building asset. Starting from the study of maintenance processes it was possible to define the information needs that will be managed by a common data environment support associated with BIM models of buildings. Furthermore, thanks to the aid of Mixed Reality (MR), the flow of information is transferred directly to the last user both as regards geometric features and for the standard procedure to be followed. This will allow a maximum optimization of data management procedures due to an automation of processes that will result in a lower incidence of errors in the processes leading eventually to an increase in quality and productivity.

Keywords: BIM, common data environment, mixed reality, operation and maintenance, Bim Server (controllare numero max parole chiave)



chair: Jesus M. de la Garza

Creative Scheduling

16:15-17:45 Monday – 2 July 2018

Influence of network structure on schedule performance – Extending criticality index to capture ripple effect of delays

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Many construction projects suffer delays. This situation is exacerbated in larger projects with their more complex schedules, **because of a 'ripple effect'** – the phenomenon that relatively small delays of activities may not just locally affect direct successors in a network schedule, but spread, accumulate, and globally impact its project finish date negatively. This research therefore studies the occurrence and behavior of said ripple effect by examining dependency structures of network schedules systematically. Its contribution to the body of knowledge is threefold: First, it develops a methodology that multiplies the elements from the correlation coefficient matrix with the reachability matrix to measure said ripple effect. It plots the cumulative product matrix in three dimensions to visualize the relative potential ripple effect of individual activities. Second, it conducts a sensitivity analysis by experimenting with schedule structures that range in complexity from sequential to parallel. A constant relation is found that the sum of the product of elements in the noncumulative productive matrix and its corresponding criticality index always equals one. Cruciality is defined. Third, it substantiates its results by simulating a benchmark schedule and derives practical suggestions for delay avoidance and delay analysis that considers how the network structure determines the behavior of a schedule.

Keywords: beta; delay analysis; ripple effect; schedule performance; simulation

A simulation-based approach for optimal construction planning and scheduling

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Project schedules in construction are responsible for an efficient deployment of resources on the job-site and for the overall efficiency of work progress. Current approaches too often lead towards sub-optimal work plans or, sometimes, even scarce productivity. For that reason, a lot of research was devoted to the development of automated scheduling tools, which can provide optimal solutions while requiring reasonable computational effort. As a consequence, planners can save their time and involved resources can benefit from the efficient organization of work packages and tasks. However, automation in construction scheduling is a tough challenge, because it requires to generate and optimize multi-objective problems, which usually include several parameters. In addition, deviations from what expected is quite frequent, and these algorithms should be able to quickly revise the previous plan, in fact performing dynamic planning. Hence, this paper presents an agent-based approach, which can be integrated in a BIM-based platform to perform automated scheduling of construction works. The BIM component can provide instant access to relevant information, which must be integrated with some user defined inputs, in order to feed the optimization algorithm. This algorithm was based on the multiple ant colony system for vehicle routing problems with time windows, because it can handle several resources travelling through many locations, each one performing its task, even in the presence of time constraints. The optimization was performed with respect to both overall makespan and total costs. An application to the case of bored piles execution will be presented in this paper.

Keywords: construction planning; scheduling automation; agent-based simulation

Employing critical chain and lean concepts to develop the planning and control framework for linear construction projects

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A framework to plan and control construction projects by incorporating the concepts of critical chain, linear schedule, and lean construction is presented. Construction project managers need to seek the effective interaction between the variables of time and money to ensure the development and compliance of the project within the planned schedule and the budget limit. Such an interaction could further be complicated by the development of project activities involving multiple stakeholders such as specialized subcontractors in different areas of construction. Consequently, this multi-participation consists in determining the start and end of all activities carried out by different parties, as well as variations in productivity each subcontractor possesses, which greatly increases the risk of project delay and over budget. Although various methodologies have been employed to prevent such problems, lacking of control mechanism and risk management lead to ineffective practice in the real project.

This framework initially integrates CCPM (Critical Chain Project Management) and LSM (Linear Scheduling Method) to create a project buffer able to control the project in terms of time. The project buffer is obtained through the reduction of the duration of some activities belonging to the critical chain through the bonus-penalty system. In Addition, a cost buffer is included within the framework to encourage subcontractors to improve their productivity and to ensure continuity of the work, respectively. Furthermore, this study incorporates concepts from Lean Construction and EVM (Earned Value Method) for the purposes of (1) managing construction projects with a higher planning reliability and (2) monitoring and controlling the consumption of project buffer and cost buffer according to established consumption criteria.

Keywords: Critical Chain; Lean Construction ;Linear Scheduling

A framework for modelling masonry construction using Hybrid simulation approaches

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Labour is a crucial resource for construction projects. More risks are associated with this than with other resources, such as materials and equipment. Contractors need tools to make more precise estimations concerning labour productivity that will allow them to minimise these risks and manage labour resources in the most efficient way possible. To achieve this, use can be made of construction simulation techniques, however, depending on the complexity of the problem, applying a single simulation approach might not be enough to appropriately model construction. Hybrid simulation approaches seem to be suitable because they combine the advantages of their components to reflect the dynamic nature of construction processes better and consider the number of uncertainties. Hybrid approaches can combine traditional discrete-event simulation (DES), agent-based modelling (ABM) or system dynamics (SD) with each other or with, for example, fuzzy logic (FL) to better capture the factors influencing productivity. To address these issues, a framework for modelling a masonry construction process that uses hybrid simulation is presented. Because masonry works are one of the most labour-intensive construction processes, and skilled labour resources are scarce, the use of such a framework would help contractors to make more realistic schedules based on accurate labour productivity estimation; thus, enabling them to utilise their resources more efficiently.

Keywords: agent-based modelling, discrete-event simulation, fuzzy logic, hybrid simulation, masonry, productivity, scheduling, system dynamics

Dynamic 4D space planning using chronographical modeling

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Over the past decade, many studies and software have combined the 3D digital models of the BIM (building information modeling) with the traditional Gantt / Precedence scheduling networks to simulate a 4D modeling for construction projects. These simulations demonstrate the sequences of the work implementation with the aim of correcting scheduling errors, resolving execution conflicts and optimizing the work plan. Originally, BIM models were intended for design perspectives. However, when applied to the construction and operation phases, they require significant efforts to revise the schedule and the BIM model, particularly to characterize the spatial nature of the projects. Modeled with a method that demonstrates a bar Chart, better known as Gantt diagram, that uses the Precedence logic, construction projects schedules represent graphically the activities, their constraints, their floats and the critical path. Despite the almost exclusive popularity of this method, its representation of the construction operations remains deficient. This logic ignores the spatial site occupation aspect related **to operations and teams' rotation**, traffics and intermediate stocks. Space planning schedules methods represent a good solution to these gaps. The Chronographic modeling, a space planning method has the ability to alternate between visual representations approaches using a set of graphical parameters. Each approach can help to model adapted schedules for different project types and specialties, shows valuable information in a clear and comprehensible manner and facilitate solving construction site problems visually. The purpose of this paper is to present a communication strategy between a 3D-BIM model, the Chronographic Modeling, and a 4D simulation tool. The development process consists of four steps. The first is to set the numerical parameters to adapt the model to space construction management perspectives. The second studies the different possibilities of communication between the three models. The third presents the scheduling through the Chronographic Modeling and the last one concerns the 4D simulation.

Keywords: BIM; 4D; chronographical modelling; scheduling; space-planning

New precedence relationships for modelling so far unsolvable projects: a theoretical review with a practical example

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A surprisingly challenging student assignment is introduced and discussed in this paper. The overall goal of the assignment is to teach students of Construction Management through personal experience that planning construction projects in advance can pay back later, and it is not about creating a schedule in a form of a network, bar chart, LSM diagram etc. A problem can have many solutions and planners can save money and time if they do not satisfy with the first results and devote more time for finding better solutions. The project can be summarized as follows: Conduits are built in three parallel roads. The same four activities (A- Earthwork, B -Pipe layout, C- Refill, D- Construction of new pavement) are carried out in each street, and there is only one team for each type of activities. Due to the different geometries and soil conditions the execution time of the similar activities are different. Two days of safety distance must be ensured between A and B, B and C, and C and D on each street. Daily cost for all the four teams are given. Materials are provided by the client so they are not part of the project cost. Teams must be payed from the first day they start to work until the last day they finish their work. Also, some indirect cost arise from the start of the project till the finish of it (cost of project management, secure site etc.) which is defined as a constant daily amount. The goal is to find a schedule that satisfies these requirements. A solution with the least cost is considered the best. This problem cannot be solved using traditional network scheduling methods. A solution using some latest developments such as bi-directional relationships, point-to-point relationships, and continuous relationships is presented and explained.

Keywords: network technique, Precedence Diagramming Method, bi-directional relationships, point-to-point relationships, OR relationships, continuous relationships



Abstracts of poster
presentation

P-01

BIM and architectural heritage

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Heritage buildings are crucial in the human perception of culture and identity over time. The sustainable retrofit of these buildings is an opportunity to reuse them taking into account sustainability. HBIM tools (historical building information models) can be used as a comprehensive data collection of information, particularly in the area of building restoration. Based on an international interesting on this kind of studies, the reconstruction process is carried out using BIM software, which shows attention on the software methodology and model structure, and at the same time clarify the added value of a BIM approach, when compared with more traditional CAD modeling systematics. Of particular interest is the approach integrating with more traditional 2D documents and for visualizing reconstruction assumptions within the 3D model representation. BIM focuses mainly on a structured approach to the overall analysis of the architectural object and the organized archival of the reconstruction project. Though virtual reconstruction is not an innovation, this paper explains the methods of preservation of architectural heritage, and the stages of BIM implementation in the digital reconstruction and restoration this kind of buildings and the most important techniques used. Also, explain the application of BIM for modeling and information presentation in different formats. The house of Hamed Saeed in Egypt built by Engineer Hassan Fathi in 1941, is an example. Beside of other examples from different countries worldwide and have just studied by this techniqueClick here and insert your abstract text.

Keywords: BIM; modeling; reconstruction; restoration; software

P-02

The influence of historical conditions on time and cost of construction project

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Conducting construction works in a building or in an area entered in the historic register is associated with the contracting authority's risk of incurring higher than planned costs of works, as well as delays in their implementation. In many cases, these deviations are completely independent of contracting authority and contractor. The aim of this article is to indicate the reasons for cost and time changes in the construction project, which is influenced by the historical conditions of the building site's location. In practice, the detailed considerations presented in the article may contribute to increasing the efficiency of spending public funds in the implementation of construction projects of a specific nature. Based on the selected example - reconstruction of the Old Pharmacy building located in the historic part of the old city of Gdańsk, the authors analyze and classify factors affecting the cost and time of construction works taking into account the historical conditions of the location of the facility.

Keywords: construction project; contracting authority; historical conditions; location; time and cost factors

P-03

Risk sharing in the construction work contracts

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By signing a contract for construction works each of the parties assumes a specific scope of responsibility. In practice, there are numerous examples of contractual provisions that violate the **parties'** safety and the balance of fair and even distribution of risk. Asymmetry in risk allocation in construction contracts and its consequences is the most common cause of disputes between the parties. The article presents the issue of risk distribution and its consequences on the example of selected construction contracts provisions.

Keywords: contractor; contract for construction works; investor; ordering party; risk

P-04

Firm's characteristics as a determinant of firm's growth

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There is increasing evidence of the role firm characteristics plays in recognition of a firm within its niche environment. However, much has not been explored into firm's characteristics to ascertain the full benefits associated with that feature. This study, therefore, explored into firm's characteristics as a determinant of firm's growth. Primary data through the used of the questionnaire assisted in gathering relevant information from 20 sampled small and medium-sized construction firms randomly selected within the Greater region of Accra in Ghana and its sub-metropolis. Data were analysed with the aid of statistical package for social sciences (SPSS) version 24 using exploratory factor analysis technique. Findings from the study revealed significant factors that influence firm's characteristics and further contribute to the entire growth of a firm. This study also established that small and medium-size construction firm's growth is impacted by vigorous characteristic features which encourage and bring about integrated results the firms and the entire industry.

Keywords: characteristics, determinant, firm, growth

P-05

Investigating the productivity based system of labour intensive works in delivering road infrastructure in rural communities in Ghana

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The Labor-intensive Public Works (LIPW) has rehabilitated 792km Feeder Roads, 192 Small Earth Dams & Dugouts (that is ensuring the harvesting of 21,195,764 cubic meters of water for the rural poor) and 2,550 hectares of degraded public/community land through tree planting and other biodiversity restoration activities. However systematic operations risk-rating on Technical Design of Project was rated low. The aim of this paper is to investigate the Productivity based system of Labour Intensive Works in delivering road infrastructure in rural communities in Ghana. The objectives are to identify the drivers affecting performance of management- and control-related activities that occur in during labour intensive works and to determine the characteristics of workers that affect the performance of labour intensive works. Purposive sampling technique was adopted to select 12 districts where the labour intensive projects on road construction were carried out. Random sampling technique was adopted to select 24 contractors from the study population which has total contractors of 180. Furthermore stratified sampling method was adopted to select 120 participants of which 24 of them are facilitators, 24 time keepers, 24 site engineers, 24 contractors, 12 district engineers, 12 GSOP Desk officers. The study adopted the exploratory factor analysis. The exploratory factor analysis was used in this research study to confirm the reliability and validity of labour productivity. Attitude of site personnel was ranked as the leading factor influencing the management related activities with a mean score of 3.81 while Knowledge of project technology and Accuracy of technical information followed having a mean score of 3.60 and 3.50 respectively.

Keywords: Ghana; labour intensive works; productivity; road; task

P-06

Automation of Davidovits theory in construction using mobile laser robot

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The truth behind the approach of building the Giza pyramids (Egypt) is still unknown. Many postulates were proposed. Noted in the past years the theory of Professor Joseph Davidovits indicating that the pyramids were “assembled” in place by heating the mud. This was proven by the identified amount of water found in the test of the nanoparticles. The advantage of such approach is bypassing the mobility and weight issues of the stones. In this paper we offer a simulation of the construction process using a multipurpose robotic manipulators. The role of this mechanism is to inject mud and heat it using LASER technology.

Keywords: automation of construction processes, modeling mobile robot, robot control, Davidovits theory

P-07

Evaluation of the construction project success with use of neural networks

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Construction project success is determined in terms of cost, schedule, performance and safety through many events and resultant interactions, plans, facilities and changes in participants and the environment. In the construction industry there are myriad uncertainties that make management exceedingly complex. Factors for success vary from project to project. Human experts can often achieve a satisfactory project outcome, however, shortfalls nearly always occur due to managers failing to take all relevant factors into consideration, in addition to lacking access to all relevant information. Statistical methods represent a basic approach to identifying significant factors from historical data or questionnaire results. However, the dynamic nature of critical factors means that changes in project conditions must be monitored continuously. Artificial intelligence techniques have a wide range of applications, including monitoring and forecasting of long-term projects; their main advantage is the ability to track and predict trends in changing project implementation factors. In this article, the authors describe the structure and algorithm of the neural network for assessing the success of construction projects, taking into account the individual influence of the initial conditions as well as their combined impact.

Keywords: construction project success, neural network, artificial intelligence techniques

P-08

Technology, structure formation and properties of foam concrete on activated water of mixing

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The results of studies of the foam concrete on activated water of mixing with the use of two types of foaming agent are demonstrated. It has been shown that activation of the mixing water increases the multiplicity and foam stability. The use of activated with the electromagnetic field and electric current water of mixing enhances strength characteristics and reduce shrinkage deformation of composites. The increase of water resistance of foam concretes prepared on activated water of mixing compared with control compositions it was established. The comparative characteristic of foam concrete on the two types of foaming agent is given.

Keywords: foam concrete, composite, activation water of mixing, foam stability, foam multiplicity, durability, water resistance, shrinkage

P-09

Comparative review of assessment methodologies of building embodied energy

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According to a report of UNEP, the building sector accounts for 40 percent of the total energy consumption in the world and is related with 33 percent of global greenhouse gas (GHG) emissions. During the whole life cycle of a building, the total energy consumption can be classified in two categories: embodied energy and operational energy. Operational energy means the energy consumed by a building to support its operation and maintenance; while the embodied energy is defined as the energy consumed in producing of a building, including the building material production, on-site delivery, and construction. Plenty of efforts have been devoted into the reduction of the energy consumption through the operational phase, however, there is a controversial about the evaluation methodology of embodied energy due to the lack of regulation or uniform standard. Currently, there are three prevailing methodologies to assess the building embodied energy: Process analysis, Output-Input analysis, and Hybrid analysis. The measurement procedure, requirement of database, system boundary, labour and time input as well as the evaluation result are all different. The evaluators need to select the suitable methodology to achieve their evaluation objectives. With the aim to give out a reference for the selection of methodology, a comparative review is conducted to compare the advantages, disadvantages, and feasibilities of the three methodologies; and the appropriate methods for different regions in the world are also pointed out.

Keywords: embodied energy, LCA, process analysis, input-output analysis, hybrid analysis

P-10

Fuzzy logic model for initial project screening with consideration of decision position

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In planning for a construction project, the owner often has several alternatives regarding the site or the building that are available for selection. Evaluation of the project alternatives and then ranking them in preference so as to select the overall best one for implementation is the key issue that influences project success. This paper proposes a model for initial **screening of project alternatives with consideration of the owner's decision position** that is reflected by the priority differences between the decision factors. The model uses the fuzzy inference system to perform mapping from the estimates of the factors or the inputs for an alternative to its score or the output. In order to illustrate the model, hypothetical alternative sites of a housing project for a developer firm are assumed and an example fuzzy inference system is built to simulate evaluation and ranking of them. First, three variables, i.e. project size, project conditions, and unit development cost, are used as the input variables that determine the desirability of a site in initial project screening. Next, the linguistics values of the input and output variables each are defined with a set of membership functions. Then, the fuzzy rules that **represent the owner's decision position** in a possible scenario are set up. For given inputs, the output is produced by mathematical operations on the rules. The assessments and rankings obtained are found to be consistent with the inputs for the sites and the decision position, showing that the model can capture the effect of nonlinear input-output relations and is potentially useful for initial project screening.

Keywords: decision position; evaluation; fuzzy logic; housing development

P-11

An assessment of construction procurement systems for public urban infrastructure projects

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Project delivery systems play a significant role for the success of public urban infrastructure projects. Without clear and precise procurement selection techniques projects continue to contribute negatively towards infrastructure development. Therefore, the purpose of the study was to determine effective groupings of construction procurement systems for public urban infrastructure projects in South Africa. The data used in the study was derived from primary and secondary sources. Out of the 150 questionnaires distributed, 91 questionnaires were usable, representing 61% response rate. Data from the survey was analysed using exploratory factor analysis. Findings from the data analysis revealed that characteristics of traditional procurement system, develop and construct, management contracting and construction management should be incorporated for public urban infrastructure projects in South Africa. The study recommended that traditional procurement system, develop and construct, management contracting, construction management and project management continue to be utilised for public urban infrastructure projects. However, projects continue to fail as a result of these project delivery systems, therefore the study recommends that processes used to select project delivery systems should be clearly stipulated and dissected before the commencement of any project. Attention should be given to characteristics of different public urban infrastructure projects, as well as the forms of contracts incorporated.

Keywords: project delivery systems; project success; public urban infrastructure; South Africa

P-12

Perceived impacts and solution to poor project management on abandoned construction projects

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The menace of missed project objectives such as schedule and cost target overruns with distressing regularity and backlogs of projects waiting to be tackled have largely characterized the construction industry, especially in developing countries like Nigeria. These occur as a result of many unidentified factors (including poor project management) which eventually lead to project failure. This study aims at investigating the perceived impacts of poor project management on abandoned construction projects and the methods that can be used to reduce the impacts. The study employed the survey research design method. The study obtained information from 66 construction profession in Lagos, Nigeria to treat the objectives. The results of the study were analyzed with SPSS software using frequencies, percentages and mean item scores. The results of the study show that, the impacts of poor project management on abandoned construction projects and its stakeholders are conflicts, loss of economic value and reduced standard of living among the citizens. The methods of reducing the identified impacts through project management include adequate planning, use of competent professionals and standard project management procedure. The study concluded that, to reduce project abandonment on construction projects, project managers must incorporate adequate planning, cost control and resource management into their services and engage experienced professionals.

Keywords: cost overrun; cost control; project failure; project management; project planning

P-13

Optimizing organizational structures in real estate and construction management

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Recent management issues are dominated by the term of efficiency. In particular, when it comes to projects in Real Estate and Construction Management, resources, namely time and budgets are running short. Thus, increasingly complex projects need nevertheless to be carried out in less time and on tight budgets. On this background, methods to optimize the consumption of goods and services are being developed using the given computational power on numerical techniques. These are based on the formulation of systems via the theory of systems or graphs down to a level where each variable is represented by an element and all interdependencies can be written as functions of all other variables. If one of the variables is declared to be optimized, a state-vector (set of parameters) can be found which matches the given demands respectively, absolutely or at least heuristically close to the optimal situation. Yet, all this rests on the fundament of a pre-set structure which is not subject to optimization but has a major influence. E.g. the predefined hierarchic setup of responsibilities allows only for a limited degree of optimization, while further development would possibly demand fundamental changes of the underlying structure. Only few optimization algorithms, e.g. derived from the traditional transport or assignment algorithms, address this situation by formulating all-encompassing structures where parameters represent the strictness of impact and are thus subject to structural optimization to some degree. In this paper we propose a set of criteria which allow to build truly sensible, i.e. optimized structures, before optimization methods with focus on parameters are applied to the system. Based on fundamental aspects like reduction of complexity, sensitivity towards modifications, stability and long-term behavior, optimization of structures instead of parameters will be available providing an appropriately predefined organization in particular for unique Real Estate and Construction Management projects.

Keywords: complexity; construction projects; hierarchical structures; optimization; real estate

P-14

An investigation of leadership styles of construction professionals in the South African construction industry

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The South African construction industry has a bearing on the economic abundance of the country. Consequently, maximum productivity is required; and to achieve this, proper leadership is one of the major factors that are needed. Literature suggests that there is huge leadership challenge among project leaders and professionals. However, little prominence is been given to the leadership competence of construction professionals in South Africa and other developing countries especially in practice. The main objective of this paper is to investigate the predominant leadership styles among construction professionals in the South African construction industry. The primary research data were collected through a structure questionnaire survey conducted on construction professionals in the Gauteng Province of South Africa. The secondary data were collected from literature review. Respondents were selected using heterogeneity and convenience (purposive) sampling techniques. Data from the questionnaire were analyzed using Statistical Package for the Social Sciences (SPSS) version 22.0 software. Mean values and standard deviation were computed. The rank of the predominant styles among the identified construction professionals was established. Findings from the study revealed that the three leading predominantly used leadership styles among construction professionals are democratic, transformational and transactional leadership styles. In addition, the results revealed the predominant leadership styles used among each construction professionals in the South Africa. The study contributes to the body of knowledge by increasing awareness about the essential of leadership and the proper use of its styles at any given circumstance within the South African construction industry.

Keywords: construction industry; leadership style; construction professionals

P-15

Critical leadership factors to enhance workers performance in the South African construction industry

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Leadership is known to be linked with construction workers' performance. Literature suggests that construction workers' morale and engagement are boosted by effective leadership. For South African construction industry to play its part effectively in the Gross Domestic Product (GDP) of South Africa, increase in productivity is vital. Hence, to achieve this goal we cannot negate the need for quality leadership among our project leaders and construction professionals. The main objective of this paper is to investigate the critical **leadership factors essential for the enhancement of construction workers' performance for effective project delivery in the South African construction industry.** The primary research data were collected through the use of a structure questionnaire survey targeted at 81 construction professionals in the Gauteng Province of South Africa. Respondents were selected using purposive sampling technique. Data from the questionnaire were analysed using Statistical Package for the Social Sciences (SPSS) version 22.0 software. Mean values and standard deviation were computed. The ranks of the critical leadership factors to **improve workers' performance were established. Findings from the study revealed that** effective communication within the project environment and proper planning of work for the workforce are of the optimum importance for performance enhancement and effectiveness. The study also revealed that the enlistment of subordinates in a common vision by appealing to shared aspirations contributes to optimum performance. It further revealed that good dispute management, continual search for innovative ways of improvement, setting exemplary actions by the leader, proper supervision of work, regular meeting with subordinates, and contingent rewards for job well done are all essential for organisational effectiveness and performance enhancement. The study contributes to the body of knowledge on the effects of effective leadership on project delivery and in turn project success in the South African construction industry.

Keywords: construction industry; leadership, organisational success

P-16

Collusion and bid rigging in the construction industry: case studies from Poland

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Polish economy experienced significant changes during the past 30 years. System transformation that began in the 1980's and was enhanced by Poland's entry to the European Union in 2004 significantly influenced economic development. Apart from tough history experiences, they formed the shape of national economy which can be observed nowadays. It was a long and difficult process. During political and economic rapid changes greater numbers of price collusions and other illegal practices can be observed than during the stable development of national economy. Authors selected and reviewed the most important anti-competitive cases in the construction industry from the past 30 years in Poland. The review includes not only cases that were officially justified and penalized - like the collusion of portland cement big producers - but also cases of collusion suspicion on highway and express roads that ended with acquittal court verdicts.

Keywords: bid rigging ; case study ; cement cartel ; collusion ; collusion detection ; highway ; public tender; road

P-17

A study of the possibility of using ground waste glass as a replacement for cement in cement composites

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The paper presents the results of tests of cement composites in which a glass substitute derived from municipal waste was used as a partial replacement for cement. The tests used a glass cullet made of brown glass, which after rinsing to remove sugars and other impurities, was dried and ground to a fraction below 125 μm . Cement mortar samples were made, in which cement was replaced with: 3, 5, 10 and 20% of glass powder. Heat of hydration of the paste and the consistency of fresh mortars and mechanical properties of mortars after 28 days of curing were analyzed. The best results were obtained for mortars with a 5% share of glass powder. The research shows that the binding properties of glass powder are closely related to the degree of grinding of the waste, and when significantly ground, they may exhibit pozzolanic properties.

Keywords: cement composites, ground waste glass, recycling, mechanical properties

P-18

Use of a 3D scanner for imaging concrete sample surfaces abraded with the ASTM C 1138 method

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In the case of most concrete constructions, aggression caused by abrasion is not the basic type of destructive environmental impact. However, in the case of certain structures, such as hydraulic constructions, it is indeed a basic impact. In addition to corrosion, the largest proportion in the general destruction of concrete hydro structures is made up by erosion from debris, wind and ice. In tests of abrasive wear on concrete, the so-called underwater method, which is described in detail in the American Standard ASTM C 1138. The abrasive wear of a concrete sample is the result of the surface impact of test steel beads placed in water and set in motion by means of a stirrer. The result of the test is the average sample area consumption, calculated using the weight loss of the concrete sample during the test. However, this method does not allow for an accurate display of the sample surface. There is no possibility of determining the size of the maximum wear of depth.

In surface imaging tests of concrete samples subjected to abrasion, in the device using the ASTM C 1138 method, an Atom Triple Scan GOM optical scanner was installed on an industrial robot with an integrated rotary table. Thanks to the use of a 3D scanner, it was possible to compile a map of the concrete sample surfaces. The scanner software allowed cross profiles to be made at any place in the samples tested. Thanks to the exact depiction of the abraded concrete surfaces used, it is possible to properly assess the concrete used in hydraulic constructions and as a repair material.

Keywords: abrasion resistance; 3D scanner; surface damage; hydrotechnical construction; underwater method

P-19

A probabilistic model for evaluating the impact of prepositioning of rescue centers of earthquake consequence management

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This study puts forward a probabilistic model for evaluating the impact of the prepositioning of rescue centers on earthquake consequence management operations. In urban areas, a disaster such as an earthquake can lead to severe casualties. Failure to provide timely medical services can increase the number of earthquake fatalities. Rescue teams can play a critical role in reducing the number of earthquake fatalities by helping those injured in the shortest possible time. In this regard, the placement of rescue centers is critically important. A probabilistic model is needed in order to evaluate the impact of prepositioning of rescue centers on earthquake consequence management operations. The proposed probabilistic model estimates the number and the distribution of the earthquake casualties based on the severity and time of the earthquake as well as the vulnerability of the buildings in the affected area. It also takes into account the expected time spent on rescuing individuals from each affected building as well as the expected time each rescue team spends traveling from one affected building to another. The model also takes into account the consequences of delays in rescuing the earthquake casualties in terms of loss of life and exacerbated injuries, and characterizes these consequences in monetary terms. This probabilistic model can be utilized in order to determine whether the existing rescue centers are appropriately-positioned and adequate, and, if not, identify the candidate positions for establishing new rescue centers before disaster occurrence.

Keywords: uncertainty; healthcare; earthquake; location analysis; rescue center

P-20

Identifying and analyzing BIM specialist roles using a competency-based approach

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The diffusion of BIM practices and the increasing connotation of BIM contributed to the emergence of several BIM-based specialist roles within the Architectural, Construction, Engineering and Facility Management (AEC-FM) sector. Both the competencies of each specialist role and the potential areas of competency overlap across these roles are not clearly identified in both academic and industry literature. Addressing this gap is important for: creating vocational and tertiary learning opportunities; supporting performance improvement of individuals and potential certification schemes; and defining roles within contract and on projects, and drafting recruitment profiles.

The paper aims to identify the competencies for four key BIM specialist roles – selected based on their citation frequency – and analyze their competency overlap. Three knowledge sieves are used to identify the BIM roles and their competencies: academic literature; national BIM guides and specifications from the UK, US, Norway, and Finland; and job advertisements (i.e. 263 job postings). A BIM competency framework for individuals (i.e. [1]) was adopted while dissecting and collating the roles and **responsibilities. The roles and responsibilities were dissected using the framework's** competency sets and topics. Social network analysis was used to visualize the competency profile of each roles, the overlap between their competency profiles, and the most prescribed competencies across all roles.

The results included: (1) a competency based profile of four BIM specialist roles, namely the BIM Manager, Information Manager, BIM Coordinator, BIM Technician; (2) an identification of the competency overlap between each pair of roles and across all roles; and (3) an identification of the competency sets and topics that are required by most roles.

Keywords: BIM; Competency; BIM Coordinator; BIM Manager; Information Manager; BIM Technician; Social Network

P-21

The development of a questionnaire survey to investigate the critical risk factors in oil and gas pipelines projects

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The scarcity of data about “the probability and severity” of the Risk Factors (RFs) and “the usability and effectiveness” of the Risk Mitigation Methods (RMMs) in Oil and Gas Pipelines (OGPs) are hindering the efforts of risk mitigations in these projects. Consequently, this paper aims to develop a questionnaire survey to collect these require data to analyze the RFs and effectively evaluate the RMMs. Firstly, documents qualitative analysis were carried out to identify the RFs and RMMs in OGP projects in different countries worldwide. Secondly, an industry-wide questionnaire survey was found to be an effective quantitative approach to analyze the “probability and severity” levels of the RFs and to evaluate the “usability and effectiveness” degrees of the RMMs. A pilot-like survey was significantly needed to improve the clarity of the questions and revise the ambiguous questions. As well as, to add the necessary queries and discard the unnecessary ones. Moreover, the pilot-like survey was used to test the functionality of the rating scales; and to improve the overall design of the survey. This survey filled by a number of experts in OGP projects; their feedback was found helpful to write the final draft of the survey. The findings of this paper was a questionnaire survey that will be used in ongoing research about mitigating the RFs in OGP projects. Furthermore, a few authors explained their procedure of designing such survey. Therefore, researchers in this field could use the findings and comments of this to design their surveys.

Keywords: Oil and gas pipelines (OGPs), risk analysis, Risk Mitigation Methods (RMMs), questionnaire survey, pilot-like survey, stakeholders perceptions

P-22

The analysis of the influence of the corrosion protection method of selected steel elements on the steel structure life cycle costs

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Steel products are widely used in the construction for the performance of essential and additional elements of engineering structures. They are characterized by high tensile strength, compression and bending, the structure homogeneity, the possibility of assembly regardless of the season and climatic conditions, ease of processing and the possibility of almost any shape. The main disadvantage of steel structures is their high susceptibility to corrosion, which depends on local operating conditions and the type of applied corrosion protection system.

The aim of the research carried out by the authors is to indicate the possibility of reducing the costs associated with anti-corrosion protection, incurred at the stage of operation of the steel structure over a period of several decades. The scope of the research includes the life cycle cost analysis for selected steel elements using three alternative corrosion protection systems. The subject of the research is the analysis of the influence of the corrosion protection method of selected steel constructions on its life cycle costs.

On the chosen example of the selected object and problems related to its use and maintenance, the possibility of using a singlelayer protection in the form of a metallization coating made in a hot-dip galvanizing process, a three-layer varnish coating based on liquid paints and protection composed of a galvanized metallization coating and a two-layer paint coating is considered. The assessment is carried out in accordance with the life-cycle cost estimation algorithm (LCC).

Keywords: steel construction; steel protection; life cycle cost; anti-corrosion protection; corrosion

P-23

The rigid and flexible road pavements in terms of life cycle costs

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The cost of road pavement construction, its durability and reliability depends on many factors, including: the scope and detail of the technical design, quality of work but also the scope of works related to its maintenance, conservation and operation. Determining the amount of rational expenses, in terms of the life cycle cost of the pavement, requires determination and consideration of the above issues, already at the planning and design stage. In many cases, the ordering party analyzes only the initial investment costs, omitting the operating expenses for the pavement in the long term. The article points out the link between decisions taken at the planning and design stages and expenses incurred at the stage of maintenance and use of road pavement. The authors analyse and compare life cycle costs for two technologies of making road pavement - flexible (asphalt pavement) and rigid (portland cement concrete - PCC) and three categories of road traffic. Referring to the methodology included in [1], the authors present an example of the LCC analysis and determine the individual cost components: construction, renovation and maintenance during the period of 30 years. The analysed costs were determined based on the expert knowledge and current price publications.

The authors draw attention to the fact that low costs incurred by the ordering party at the stage of investment implementation, in the course of use and maintenance of the pavement, entail significant expenses in the long-term. The authors also indicate difficulties related to the estimation of the cost of the road pavements life cycle.

The main reasons include the lack of designers' knowledge about the technology of pavement repairs and related costs, as well as the lack of a simple model for calculating life cycle costs, which is a tool for supporting investment decisions and indicating the optimal solution already at the design stage.

Keywords: road pavement construction; life cycle costs; LCC analysis; flexible pavement (asphalt); rigid pavement (concrete)

P-24

Enhancing Lean Concept in precast concrete manufacturing with advanced Material Requirements Planning System

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Companies operating in the construction industry, like many other companies in the manufacturing industries, in order to maintain their position on the global market, optimize inventories and the production processes. The need to minimize costs and maximize profits from manufacturing, while maintaining a high quality of products means that the "Lean manufacturing" concept must be implemented in all departments of the precast concrete production company. Delivery of prefabricated elements to construction sites is currently carried out based on detailed delivery schedules. These conditions mean that the "Just in time manufacturing" methodology is implemented in the precast concrete production companies. The high costs associated with the need to maintain stocks and resulting from the cost of creating the inventory and cost of maintaining the inventory are certainly not without significance. Achieving these goals is not possible only through detailed production planning, accurate cost determination, better use of storage and manufacturing infrastructure and forecasting sales volumes. In this case, considering the current reduction of inventories, accurate determination of delivery times of raw materials and semi-finished products is also important. The purpose of this paper is to present the method of planning material requirements for precast concrete manufacturing plants based on the MRP (Material Requirement Planning) system.

Keywords: construction industry, lean concept, material requirements planning, precast production

P-25

Identifying infrastructure project uncertainties during project initiation using system thinking

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This paper describes a system thinking conceptual framework which will be utilized in identifying uncertainties in infrastructure project during initiation stage deduced from literature review. It forms part of an ongoing PhD research project whose aim is to improve costing in infrastructure project to accommodate uncertainties. The paper concludes that system thinking approaches will enable key stakeholders in infrastructure project to identify and manage uncertainties that will impact on project goals adversely.

Keywords: Infrastructure project, System thinking, Uncertainty/Risk & Conceptual Framework Design

P-26

Construction 4.0: towards delivering of sustainable houses in South Africa

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Housing is a major challenge for most African countries including South Africa which is characterized by numerous backlog of housing provision. This study seeks the adoption of construction 4.0 principles for reducing the housing backlog experienced within the country. Therefore, the study examines the impact of applying construction 4.0 for delivering sustainable and quality accommodation and evaluates the hindrance in its adoption. Construction 4.0 involves the application of industry 4.0 concepts a synonym for the 4th industrial revolution that originated from the German manufacturing sector to the South Africa housing industry with the intention of creating a digital industry using a sophisticated gadget like drones, RFID, laser scanning, 3D printing and many others. Convenience sampling method was used in obtaining data from practicing construction professional in Johannesburg Gauteng province South African. A total of 184 questionnaires were obtained from the construction professionals out of 220 that was distributed. The data were analyzed with SPSS V 24, using, mean score, regression and factor analysis. The study discovered that there is a positive impact on the use of construction 4.0 principle for housing delivery as it reduced cost and time overrun thereby ensuring the prompt delivery of affordable and quality houses. The foremost hindrance to the adoption of construction 4.0 principle is the cost of investing in modern technology by small construction firms. The study contributes to the innovative ideas for housing delivery in South African it recommends that strategies and infrastructures should be put in place towards enabling the digitization of the construction industry and increase the awareness of construction 4.0 among construction professionals.

Keywords: Construction 4.0; Digitalization; Industry 4.0; Sustainable Housing

P-27

Development of verification system of earthwork amount using 3D analysis cell

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The Efforts has been made with a fast speed to the automation of earthworks focused on global construction machinery enterprises. By using drone or terrestrial laser scanner, the work site can be measured rapidly and by using this it aims to provide various solutions to operate construction machinery effectively. In order to manage effectively the process of construction, it is important to figure out the changes of amount of earth cutting and banking with respective work site upon measuring the total volume of work in the progress of the project. In this study, the Analysis Cell introduced in earlier research is applied to the real work site to analyse the amount of work, cutting and banking. Applying to test bed, the amount of cutting and banking in the early stage were identified to have been decreased gradually in connection with the progress of works. Furthermore, based on Analysis Cell, it could be verified that work site has been changed to the similar shape of the design drawing.

Keywords: terrestrial laser scanner, analysis cell, earthwork amount, verification system

P-28

Proposal for typology and definitions of service categories in a general PMO model

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The strategic importance of project management offices (PMOs) is not questionable therefore identifying the most specific and noticeable evaluation segments of PMOs leads to a better understanding of PMOs. As a starting point in our earlier publication along with the quest for the determination of a standardized, integrated, and comprehensive framework, we defined a PMO model summarizing grounding ideas of our research. This complex PMO model contains six building blocks that describe the complex role and status of PMO within the organization: the context (the environment of the PMO), the typology, the maturity, the internal processes of the PMO, the services, and the performance (the metrics of the PMO).

This study concentrates on the services and the typology of a PMO, based on a deep dive in the different approaches of these two categories. We achieve this first by elaborating a clear description of them and secondly by analyzing the relationship between them and the other categories of the model.

In our model, among the six categories 'typology' has the most direct connection to the organizational structure that a PMO serves. Following the analysis of state-of-the art and relevant publications about this category, we recognized that the typology has various definitions leading to diffuse meaning. This research clarifies this concept to give a proposal for the exact definition of typology.

Publications on PMO 'services' do not emphasize the definition itself enough. Instead, they focus on the PMO responsibilities within an organization, the needs, and the objectives to achieve. Our research provides a collection of all the service elements, and different grouping concepts of them. In his study we suggest a unified list of PMO services, their descriptions, and a grouping approach in line with the aim of PMO operation.

Keywords: project management office; evaluation framework; maturity; services

P-29

How DEWA increased efficiencies and value by using streamlined project management processes

Tarek Hassan Tawfik and Omran Al-Shamsi

This study will presents the factors to achieve project management success; In terms of standards and methodology the organizations should adopt to achieve the values and benefits of project management. Multi-dimensional frameworks are validated and used in this study to measure project management performance and project success.

Dubai Electricity and Water Authority (DEWA) delivers worldclass services of electricity and water that meet the highest standards of availability, reliability and efficiency. DEWA serves over 842,000 customers across Dubai, a flourishing global city considered a leading hub of business activity in the Middle East and Northern Africa regions.

Since its merger in 1992 of the Dubai Electricity Company and Dubai Water Department, DEWA has evolved and grown, measuring and adjusting the ways it serves its customers and integrating project management across the organization.

Dubai has experienced an unprecedented growth over the last two decades that transformed the city and propelled its gradual rise to global business prominence. This growth added complexity to the already daunting task of providing water and electricity services to consumers and businesses in a region with a population that exceeds two million. In 2014 alone, water connections increased nearly 30 percent, rising from 23,350 in 2013 to 30,000. The power demand increased another five to six percent in 2015. (DEWA Annual Statistics).

DEWA's leadership knows that adhering to proven project, program, and portfolio management practices reduces risks, cuts costs, and improves success rates. Top champion organizations realize the right project, program, and portfolio management practices give them a competitive edge. But there's always more that can—and should—be done. For the past six years, we have been conducting additional research to determine which factors have the most impact on project success. Based on a rigorous statistical analysis, three things rise to the top when it comes to helping organizations save millions of dollars: drivers of project success: (PMI pulse of profession – 2018)

1. Investing in actively engaged executive sponsors
2. **Avoiding scope creep or uncontrolled changes to a project's scope**
3. Maturing value delivery capabilities

P-30

Cost estimating and building information modelling (BIM) in road construction

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BIM (Building information modelling) methodology offers a modern tool for all branches of construction. The information model proceeds throughout the life cycle of the construction work and ideally it contains all the information associated with elements in the model composition. BIM 5D presents another natural step in widening the utilization of information modelling for cost management and which thus puts BIM into practice. The paper deals with the creation of quantity takeoff and budgeting for construction works derived from an information model. Interconnection of theoretical knowledge with building practice has been implemented through cooperation with two multinational construction companies operating in the Czech market. This has concerned cooperation based on putting forward information models which can apply modern technologies for creation of the quantity takeoff and further to budgeting for construction works. Particular study has been carried out on two technically and technologically similar transport projects.

Keywords: BIM; cost; quantity takeoff



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Co-organizers



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Frontiers of Engineering Management