CCC2020

CREATIVE CONSTRUCTION
e-CONFERENCE
28 June - 1 July 2020

Book of Abstracts
Creative Construction e-Conference 2020

Creative Construction e-Conference 2020

Book of Abstracts

28 June – 1 July 2020,

Editors-in-chief:	Miklós Hajdu and Mirosław Jan Skibniewski
Technical editors:	Attila Varga, Róbert Hohol, Gergely Szakáts

Keynote Lecture

How Do Planners Mislead Their Clients?
Conceptual Problems in Network Models Leading to Too Optimistic Project Duration

Miklós Hajdu

Budapest University of Technology and Economics, Budapest, Hungary
Chaoyang University of Technology, Taiwan

It is well-known and accepted among construction industry experts that projects are (often) late and finished over budget. Countless number of papers study the causes of this phenomenon and define dozens of factors as possible causes of delays. This paper hypothesizes the very rare case that: a) projects' temporal plans reflect all the technological dependencies; b) no activities affecting the project duration are missing from the plan; c) lack of resources (i.e. skilled labors, trades, equipment, and material) does not hinder the execution; d) organizational issues are also well handled. Despite of all these projects will delay and the reasons for this are due to the poor modelling capabilities of the networks and the non-adequate planning methodologies. This paper discusses the most frequently occurred planning problems and show their affect on the project duration. Finding shows that plans usually have 5 up to 50% possibility to finish in time, even if the original hypothesis holds. If not then this possibility is even less which explains why the majority of projects delay. The final conclusions of the paper are threefold: a) Network techniques with better modelling capabilities should be adopted in IT tools b) professional bodies should promote the techniques with enhanced modeling capabilities c) education should incorporate the new developments into the construction management curricula faster.

Keywords: CPM, Precedence Diagramming Method, precedence relationships, non-linear activities

4

Automation and Robotics for Construction

Application of UAS and Revit for Pipeline Design

Hamlet Reynoso Vanderhorst[1], David Heesom[2], Subashini Suresh[3], Suresh Renukappa[4] and Keith Burnham[5]

[1] University of Wolverhampton, Wolverhampton, UK, (corresponding author)
    h.d.reynosovanderhorst@wlv.ac.uk
[2] University of Wolverhampton, Wolverhampton, UK, d.heesom@wlv.ac.uk
[3] University of Wolverhampton, Wolverhampton, UK, s.subashini@wlv.ac.uk
[4] University of Wolverhampton, Wolverhampton, UK, suresh.renukappa@wlv.ac.uk
[5] University of Wolverhampton, Wolverhampton, UK, k.burnham@wlv.ac.uk

The professionals in the vertical and horizontal construction have tested methods to enhance the quality, safety, environmental impact, delivery time and cost control in their works promoted in learning organisations. Automation strategies applying robots and technology has been a focal point in industry of manufacture by its benefits in productivity levels and quality of works, and in some cases, without affecting other factors in a long-term period. The construction industry is playing a predominant economic heading in certain countries. Therefore, the adoption of Unmanned Aerial System (UAS) and Building Information Modelling (BIM) methodology as an automation strategy represent in short and long terms positive economic impact. UAS or drones have been used for cargo and data capturing in the built environment. Nowadays, the construction of infrastructures is the most benefited project from UAS implementations by gathering visual data of cracks, obstructions, energy levels, traffic and current conditions of the projects fulfilling the gap of human risks reduction, speed on data collection, and digitalisation of the real-world along with BIM. However, there is a breach in reliability and awareness on the UAS application cases in the infrastructure sector.

The aim of this paper is to present the reasons and the application case of the UAS from the topography department of a Water Supply public organisation. The findings show that the UAS achieved a higher level of productivity and efficiency in the daily pre-construction works for designing pipelines. The case covers sewer identification and georeferencing in rural areas where the satellites were unavailable to show the state accurately. The tool used was an RTK DJI Phantom 4 to survey the site conditions in BIM format. The integration of UAS in BIM showed a higher level of productivity and efficiency in the employee's workflow in terms of data collection contrasting to old-fashion methods.

Keywords: survey, infrastructure, BIM, UAS, water supply

Automated State-Survey System for Monitoring Salt Damages on Plastered Wall Surfaces

István Vidovszky[1] and Farkas Pintér[2]

[1] *Budapest University of Technology and Economics, Budapest, Hungary*
[2] *Scientific Laboratory, Federal Monuments Authority Austria, Vienna, Austria*

Salt damage is a common problem at many heritage sites and historical buildings. The accumulated salt can aggravate moisture problems, cause inconveniences in use, and physical decay of the structures, most commonly the damage of the plaster layers. Internet of things (IoT-s) are becoming part of our advanced, contemporary toolset, which in case of proper establishment and settings enables us to collect data of the investigated facilities continuously, without a regular professional presence on site. In this research, an attempt has been made for continuous monitoring by the mean of a custom-designed single-board computer-based automatic survey station. The system records environmental (i.e., temperature, relative humidity) and visual data that enables state recording on a regular base in order to monitor historic buildings for preservation purposes.

Keywords: state survey, automated diagnostic system, surface condition monitoring, building health monitoring IoT

Development of a Digital Twin Model for Real-Time Assessment of Collision Hazards

Leonardo Messi[1], Berardo Naticchia[2], Alessandro Carbonari[3], Luigi Ridolfi[4] and Giuseppe Martino Di Giuda[5]

[1]   *Polytechnic University of Marche, DICEA Department, Ancona, Italy, l.messi@pm.univpm.it*
[2]   *Polytechnic University of Marche, DICEA Department, Ancona, Italy, b.naticchia@univpm.it*
[3]   *Polytechnic University of Marche, DICEA Department, Ancona, Italy, alessandro.carbonari@univpm.it*
[4]   *Polytechnic University of Marche, DICEA Department, Ancona, Italy, l.ridolfi@staff.univpm.it*
[5]   *Polytechnic of Milan, ABC Department, Milan, Italy, giuseppe.digiuda@polimi.it*

The AEC industry is nowadays one of the most hazardous industries in the world. The construction sector employees about 7% of the world's work force but is responsible for 30-40% of fatalities. As statistics demonstrate, interferences between workers-on-foot and moving vehicles have caused several injuries and fatalities over the years. Despite safety organizational measures, passive safety devices imposed by regulations and efforts from training procedures, scarce improvements have been recorded. Recent research studies propose technology driven approaches as the key solutions to integrate standard health and safety management practices. This is motivated by the evidence that the dynamics of complex systems can hardly be predicted; rather a proactive approach to health and safety is more effective. Current technologies installed on construction equipment can usually react according to a strict logic, such as sending proximity alerts when workers and equipment are too close. Nevertheless, these approaches barely do make informed decisions in real-time, e.g. including the level of reactiveness of the endangered worker. In similar circumstances a digital twin of the construction site, updated by real-time data from sensors and enriched by artificial intelligence, can pro-actively support activities, forecasting dangerous scenarios on the base of several factors. In this paper a laboratory mock-up has been assumed as the test case, supported by a game engine, which is able to replicates the job site for the execution of bored piles. In such a scenario populated by an avatar of a sensor-equipped worker and a virtual driller, a Bayesian network, implemented within the game engine and fed in runtime by sensor data, works out collision probability in real-time in order to send warnings and avoid fatal accidents.

Keywords: artificial intelligence, building information modeling, digital twin, real-time system, real-time health and safety management

Feasibility of Using Physiological Signals from a Wearable Biosensor to Monitor Dehydration of Construction Workers

Amit Ojha[1], Shahrad Shakerian[2], Mahmoud Habibnezhad[3], Houtan Jebelli[4], SangHyun Lee[5] and Mohammad Sadra Fardhosseini[6]

[1] *Pennsylvania State University, University Park, PA, USA, azo5242@psu.edu*
[2] *Pennsylvania State University, University Park, PA, USA, sqs6689@psu.edu*
[3] *Pennsylvania State University, University Park, PA, USA, mjh6946@psu.edu*
[4] *Pennsylvania State University, University Park, PA, USA, hkj5117@psu.edu*
[5] *University of Michigan, Ann Arbor, MI, USA, shdpm@umich.edu*
[6] *University of Washington, Seattle, WA, USA, sadrafh@uw.edu*

Among major industries, due to the labor-intensive nature of most of the construction tasks, the construction industry has some of the highest numbers of heat-related illness claims. The leading cause of these illnesses is the repeated exposure of workers to heat stress, which adversely affects productivity, safety, and health. A biophysical interpretation of the body's responses to heat stress is a promising way to continuously measure the likelihood of heat stress exposure of workers. Such a method surpasses current metrics such as Wet Bulb Globe Temperature and Heat Index. The others do not account for variations of individual physiology and biometrics (e.g., age, gender, and metabolism) in response to heat stress. Also, environmentally based methods cannot be used to continuously monitor heat stress in the workplace. This study aims to examine the effect of heat stress exposure on the flux of three different physiological signals: photoplethysmography (PPG), electrodermal activity (EDA), and skin temperature (S.T). To facilitate capture of workers' physical responses to acute heat, these are acquired from a wristband biosensor. To that end, physiological data were gathered from 10 workers performing construction tasks under three climatic conditions, each with a different likelihood of exposure to heat stress – conditions of caution, extreme caution, and danger, as defined by the National Oceanic and Atmospheric Administration (NOAA)'s National Weather Service. Heart rate, heart rate variability, electrodermal activity, electrodermal response, and mean skin temperature were extracted to examine the potential of these signals for measuring workers' heat stress. The results indicated statistically significant differences in the metrics of heat stress exposure. The findings demonstrated the feasibility of PPG, EDA, and S.T. in capturing physiological changes during heat stress exposure and dehydration.

Keywords: dehydration assessment, wearable biosensors, physiological monitoring

Investigating a 24 GHz CW-Radar for Non-Contact Vital Sign Sensing in Construction Machine Cockpits to Increase Safety on Building Sites

Stefan Pehr[1], Jörg Güttler[1], Tatsuo Arai[2], Thomas Bock[1] and Mieko Ohsuga[2]

[1] Technische Universität München, Munich, Germany
[2] Osaka Institute of Technology, Umeda Campus, Osaka, Japan

The US-construction industry sector in 2018 had about 4.5 % of U.S. workers, but 19.1 % of the fatalities - the largest number [1] of fatalities reported for any industry sector [2, 3]. In this context, transportation incidents with heavy vehicles and aging workers over 55 years have the highest fatal event accounting in respect to selected events and demographic characteristics [3]. Therefore, research is underway to measure the health condition of the driver in the construction machine cockpits unobtrusive and non-interfering with their activities. Generally, in research this attempt can be divided into those based on image analysis of camera images, those equipped with wearable sensors, and the method of incorporating sensors in the workers environment, e.g. chairs, controllers, steering wheel, etc. There are various ways to incorporate sensors into the chair [4]. E.g. one of the authors is also trying to extract the driver's heartbeat and respiration information with capacitive electrodes and a pressure sensor built into the seat [5]. This paper focuses on a biometric driver seat concept based on Vinci and Leonhardt [6] using a 24 GHz CW-Radar sensor module to monitor the driver's health status. The radar sensor signal carries information about the respiration, heartbeat and motion signals of the driver by evaluating the phase-shift of the reflection wave. To separate the respiration-signal from the heartbeat-signal a digital low-pass filter with a cutoff frequency at 0.5 Hz is used. The driver's respiration rate (RR) is determined by a maximum peak detection in the frequency-domain of the radar signal. The heart rate (HR) is obtained in the time-domain by a heartbeat count estimation. The elimination of random body movement artefacts was not examined in this work. The authors' objective by this work is to improve safety on construction sites, via the proposed biometric driver seat concept, by early identification of potential health hazards of the driver. For this objective, it is necessary that the detection of human vital signs inside of the cockpit of construction machines will become a part modern driver assist and safety systems in future.

Methodology of the Nondestructive Evaluation of Pull-Off Adhesion Between Repair Overlay and Repaired Element Using Artificial Intelligence

Sławomir Czarnecki, Jerzy Hoła and Łukasz Sadowski

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

In this article the methodology of the nondestructive evaluation (NDE) of the pull-off adhesion between repair overlay made of cement mortar with variable thickness and the repaired element has been presented. For this purpose, four complementary nondestructive testing (NDT) methods have been used - the 3D laser scanning, geometric leveling, and acoustic impulse response and impact echo methods, as well as an artificial neural network (ANN) with principal component analysis (PCA). The methodology is based on the previous experimental research and numerical analyses performed by the authors. The proposed methodology contains 2 stages. Stage 1 involves the performing of laboratory tests using NDT methods on the surface of the repaired element (Stage 1a) and on the surface of the repair overlay (Stage 1b). Stage 2 involves the performing of numerical analyses using a multilayer perceptron ANN with PCA with the Broyden-Fletcher-Goldfarb-Shano (BFGS) learning algorithm. This methodology, based on the use of the complementary NDT methods and ANN, eliminates the drawback of the pull-off method, which is commonly used in construction practice in order to evaluate the pull-off adhesion value.

Keywords: repair overlay, repaired elements, interlayer bonding, nondestructive testing methods, artificial intelligence

Nested Network for Detecting PPE on Large Construction Sites Based on Frame Segmentation

Mohammad Akbarzadeh[1], Zhenhua Zhu[2] and Amin Hammad[3]

[1] Concordia University, Montreal, Canada, mohammad.akbarzadeh@concordia.ca
[2] University of Wisconsin-Madison, Madison, USA, zzhu286@wisc.edu
[3] Concordia University, Montreal, Canada, hammad@ciise.concordia.ca

Safety is a main concern for the construction industry because of the high rate of accidents and casualties on construction sites. Personal Protective Equipment (PPE) is a major part of safety regulations to prevent accidents. However, workers may neglect to wear the required PPE while working, which subsequently increases the potential risk for accidents. Currently, safety managers and inspectors on construction sites are responsible for monitoring safety regulations, which is a time-consuming task. To facilitate safety monitoring, a large number of research studies applied computer vision for detecting PPE on construction sites. Nevertheless, detecting workers and PPE is still a challenge in far-field videos. This research proposes an approach for detecting if anyone on the construction site is wearing the required PPE, even when he or she is far from the surveillance cameras. This method uses a frame segmentation technique and a nested network with two Faster R-CNN models to detect safety noncompliances. The first model detects the human bodies on the construction site, and the second one detects if the detected person is wearing a hardhat and a safety vest. The proposed method is applied to videos from a construction site. The experimental results demonstrate the practicality and robustness of the proposed method to detect PPE in far-field videos. Based on three different test videos, the average precision and recall for the worker detection model were 99.67% and 92.92%, respectively. The PPE detection model had the average precision and recall of 91.25% and 94.77%, respectively.

Providing Proximity Safety Alerts to Workers on Construction Sites Using Bluetooth Low Energy RTLS

Yusheng Huang[1], Amin Hammad[2] and Zhenhua Zhu[3]

[1]   *Concordia University, Montreal, Canada*
[2]   *Concordia University, Montreal, Canada (corresponding author)*
[3]   *University of Wisconsin-Madison, Wisconsin, USA*

Struck-by equipment is one of the main reasons of accidents on construction sites. In order to improve construction safety, previous research proposed using Real-Time Location Systems (RTLS) to track the location of workers and equipment on construction sites. However, using ultra-wideband RTLS on large sites is difficult because it needs many timing cables to synchronize the data of the sensors surrounding the site. Furthermore, providing safety alerts to workers within dangerous proximity to equipment has not been addressed in previous research. Instead, the alerts were sent only to the safety manager. This paper aims to develop a method for providing proximity safety alerts to workers on construction sites using Bluetooth Low Energy (BLE) RTLS. BLE RTLS can provide acceptable accuracy coupled with large coverage and without the need of timing cables. In addition, with the support of two-way communications between the tags and sensors, it is possible to provide vibro-tactile alerts to the workers using wristbands. A prototype system is developed to filter the location data and remove outliers using averaging over time and averaging over tags of the objects. A case study is applied on a construction site to demonstrate the feasibility and performance of the proposed method.

Keywords: Bluetooth Low Energy (BLE), Real-time Location System (RTLS), construction safety, wristband, vibro-tactile alert

Structure Equation Model for the Successful Implementation of ICT / Automation in Construction Project Management in India

Saurav Dixit[1], Priyanka Singh[2] and Krystyna Araszkiewicz[3]

[1] RICS School of Built Environment, Amity University, Noida, India, sauravarambol@gmail.com
[2] Department of Civil Engineering, Amity School of Engineering & Technology, Amity University Noida, Uttar Pradesh, India
[3] West Pomeranian University of Technology, Szczecin, Poland

Each project is unique in nature and has its own complexities associated with it, and the management of construction projects requires effective and well-organized communication between all parties and stakeholders involved in the project. Coordination and collaboration between all stakeholders are the key to the success of any project. This is the sole importance among the team members of completing any given project on time and at the required cost. ICT is a technology that can be used to enhance communication between all the parties concerned working on specific or concerned projects, including stakeholders, etc. IT-based technology has many tools and software that have the tremendous ability to ease work related to the flow of information, data collection and storage, etc. The objective of current research is to identify and analyze the factors affecting the implementation of ICT / Automation in construction projects in India using structured equation modelling (SEM). The literature review has been carried out and some attributes have been identified regarding the benefits, barriers and enablers of ICT. These attributes were included in the questionnaire prepared to receive a response from industry professionals in the construction sector. The survey was conducted in the Indian construction industry and the response of various industry professionals from top-level management and middle-level management was recorded. The data collection was carried out and the response was further analyzed. Various factors affecting the use of ICT in construction project management have been analyzed using different statistical techniques (exploratory factor analysis, reliability analysis and structure equation model). The findings of the research provided a SEM model for the successful implementation of ICT in construction projects.

Keywords: ICT, automation in construction, construction management, project management, structure equation model

Validation of a Formal Framework Model to Improve On-site Construction Productivity: Indian Scenario

Saurav Dixit[1], Dhurva Choudhary[2], Priyanka Singh[2] and Krystyna Araszkiewicz[3]

[1] RICS School of Built Environment, Amity University, Noida, India, sauravarambol@gmail.com
[2] Department of Civil Engineering, Amity School of Engineering & Technology, Amity University Noida, Uttar Pradesh, India
[3] West Pomeranian University of Technology, Szczecin, Poland

Validation can be carried out in many ways, as with most of the research work model validation is usually carried out in five main ways: retrospective project analysis, use of archival data, alternative data collection methods, replication of studies, and experimental implementation. Given the complexity of the data used to propose a framework model for on-site construction productivity, three separate validation methods have been used to verify accuracy and reliability. The validation of the framework model (structure equation model) and the hypothesis using statistical validation measures (quantitative experimental studies are ideal testing tools such as GOF, TLI, and CFI), secondly the validation of the model is by validating the seven main hypotheses using an expert panel of top management industry professionals from the Indian construction industry (using an expert panel of project managers from 13 different construction project in India). The results of the accuracy and effectiveness of the framework model were compared in both different validation processes and the findings of the study suggest that the framework model developed using the structural equation model is valid and that the model could be used by the Indian construction industry.

Keywords: validation process, framework model, construction productivity, construction management, structure equation model

Will Artificial Intelligence (AI) Take over the Construction World? - A Multidisciplinary Exploration

Souhail Elhouar[1], Elodie Hochscheid[2], M. Ammar Alzarrad[1]
and Chance Emanuels[1]

[1] Bradley University, Peoria, USA
[2] MAP-CRAI (UMR 3495), School of Architecture, Nancy, France

The late Stephen Hawking was reported to have said, "Computers will overtake humans with AI within the next 100 years. When that happens, we need to make sure the computers have goals aligned with ours." This statement is frightening to most, as very few people may like the idea of seeing computers take over the world. However, what can be more frightening is for those few people who like the idea to also make use of Hawking's suggestion and find a way to make sure the computers have goals that are strictly aligned with only theirs. There is a distinguishable apprehension among people of the role AI is set to play in the future of humanity, and this apprehension is transcending disciplinary boundaries. In the particular fields related to construction, there seems to be a genuine interest in integrating AI in each phase of a project to improve quality, enhance safety, and reduce costs, but this interest is countered by a legitimate concern that many types of jobs would be lost to AI-enhanced machines. In this paper, the authors tried to shed some light on how AI might change the face of the construction industry. The authors, spanning generations and disciplines in the industry, tried to answer the question "will AI take over the construction industry?" each from their own perspective including architectural, structural, and construction management. A synopsis of the status of the application of AI in construction and related fields is first provided, and then the authors offer their individual views with respect to how they expect AI to affect their side of the industry. This paper is an effort to gain insights into the perceptions of current and future construction related professionals of the role of AI and the impact it may have on the industry.

Keywords: artificial intelligence, construction automation, deep learning, future of construction, machine learning

Creative Construction Technology and Materials

An Investigation into the Integration of Building Information Modeling with Pre-Construction Industry in the Developed Countries and Iran

Javad Majrouhi Sardroud[1], Hamid Mehranpour [2] and Abolfazl Arzanloo [3]

[1] *Central Tehran Branch, Islamic Azad University, Iran, j.majrouhi@iauctb.ac.ir*
[2] *Central Tehran Branch, Islamic Azad University, Iran, (corresponding author),*
   Hamid.mehranpour@yahoo.com,
[3] *Central Tehran Branch, Islamic Azad University, Iran, abolfazl.arzanloo@gmail.com*

Modern methods of construction buildings to improve the quality, reduce the time and cost, and increase their productivity have always been desirable for architectural, civil and construction engineers. In the 21st century, any evolution in technology was achieved with advancement in computer science. Building information modeling is actually a simulated multidimensional model related to building geometry, spatial relationships, geographic information, the amount and properties of all building components, and their intelligent communication with each other. This technology is a new approach to building design, implementation and management at the same time with great quality and coordination. Now days with the advancements in digital architecture, prefabrication and all kinds of building design optimization, it can be seen the growing use of building information modeling system in the construction industry. For this reason, building information modeling can have a significant effect on pre-fabrication. Also, by examining the building model, planning to install prefabricated components of the building and identifying executive interfaces will also be present. This paper examines the advantages and disadvantages of building information modeling, as well as the need for this type of software for the construction industry in the world and Iran.

Keywords: building information modeling, prefabrication industry, modern methods, construction industry

Modular Construction vs. Traditional Construction: Advantages and Limitations: A Comparative Study

Karthik Subramanya[1], Sharareh Kermanshachi[2] and Behzad Rouhanizadeh[3]

[1]   *Department of Civil Engineering, University of Texas at Arlington, Arlington, USA,*
     karthik.subramanya@mavs.uta.edu
[2]   *Department of Civil Engineering, University of Texas at Arlington, Arlington, USA,*
     sharareh.kermanshachi@uta.edu
[3]   *Department of Civil Engineering, University of Texas at Arlington, Arlington, USA,*
     behzad.rouhanizadeh@mavs.uta.edu

Modular construction is a novel technique that has several advantages over traditional construction methods; however, along with the benefits, there are limitations that make it challenging. Various aspects of modular construction need to be studied in-depth to improve the construction process, and the aim of this study was to accomplish that by investigating its advantages and limitations and comparing them with traditional construction. The advantages were identified through a thorough literature review, and were classified into five categories: project schedule, project cost, labor safety, project quality and productivity, and environmental. The limitations were also investigated through the existing literature and classified into five categories: project planning, transportation, public and expert acceptance, establishment cost and cost due to complexity, and coordination. The results revealed that the advantages of modular construction outnumber its limitations; however, further technological development and research would lessen or mitigate the challenges. The results of this study highlight the main benefits and challenges associated with modular construction and will help project stakeholders choose between this method and conventional construction methods for their projects.

Keywords: modular construction, traditional construction, modularization

Opportunities for Transportation Departments to Leverage Construction UAS Data

Bryan Hubbard[1] and Sarah Hubbard[2]

[1] Purdue University, West Lafayette, USA, bhubbard@purdue.edu
[2] Purdue University, West Lafayette, USA, sarahh@purdue.edu

Unmanned Aerial Systems (UASs) are being used on infrastructure construction sites by contractors for many different applications and generate valuable data that could be potentially leveraged for Department of Transportation (DOT) applications. Representative UAS construction applications include construction progress monitoring, safety surveillance, quality assurance, documentation of work zone conditions following an incident, quantity measurement, and communication with stakeholders. The UAS data typically consists of high definition pictures and video from a standard commercial drone. Many of these constructor UAS applications directly relate to activities that are also important for DOTs such as monitoring construction activities, quality assurance, managing the safety of the work zone and construction project. This paper reviews the potential UAS applications that benefit both contractors and DOTs and presents results of a survey regarding common UAS applications.

Keywords: construction, Unmanned Aerial Systems (UAS), drone, Departments of Transportation (DOT)

Reticulated Roof Structures Optimisation Based of Triangular and Quadrilateral Planar Panels

Anna Stefańska

Warsaw University of Technology, Warsaw, Poland, anna.stefanska2@pw.edu.pl

The search for the form optimization of reticulated roof structures is a significant aspect in Architectural Engineering and Construction section. It consists of reflecting the intended aesthetic effect as well as an attempt to choose the most suitable technical solutions. Therefore the divisions of reticulated structures should be determined to pursuit of structural, material and technique of fabrication advancement. In contemporary construction practice, understanding how curved shapes describe the form becomes an significant design aspect. Structural divisions of free-formed canopies should be solved in architectural and structural design simultaneously at an early stage of designing. The choice of proper designing method becomes a complicated process, requiring the ability to selecting type of production and rationalize technical solutions mainly due to the computer aided design supported by algorithmic tools. The paper research analyzes curvilinear structures of canopies in search of optimal structures of geometrical divisions. Case study is based on reticulated roof structures with triangular and quadrilateral panelization. In recent twenty years, the most common and accessible solutions for free-form canopies are triangular divisions due to the ability to use flat glass panels. Panelized Quadrilateral surfaces, facilitate the fabrication process in many aspects, surpassing triangular panels. Their main disadvantage was the design of quadrilateral flat panel mesh. The finding of the study conclude assets and flows of both methods of shaping the geometry of reticulated roof structures based on material and technology of fabrication aspects. The study conclude that the crucial designing method is to determine the manufacturing technology in the early stage of architectural optimization.

Keywords: creative designing, generative designing, grid canopies, structural optimization, topology optimization

Creative Management in Construction

A Broader View of Risk Management Process in Projects

Zoltán Sebestyén[1] and Tamás Tóth[2]

[1] *Budapest University of Technology and Economics, Budapest, Hungary, sebestyen@mvt.bme.hu*
[2] *Eötvös Loránd University, Budapest, Hungary, totht@gti.elte.hu*

Risks have to be managed with great care so that the final goal of delivering a successful project can be reached. The paper extends the risk management process with the value-based risk monitoring framework developed by the authors, where the primary purpose is to detect and monitor risks jeopardizing the expected project return, and if necessary, to start action plans in order to avoid losses. An important characteristic of the suggested integrated model is that it takes into consideration that risks are time-varying, that is, as time passes, the uncertainty of the occurrence of a risk changes. In this paper, the traditional risk management process is extended with the value-based approach, where risk factors are measured on a linear scale. The integrated project risk management process supports the organization-level decision making, and extends the fundamental roles of project portfolio management office identified by the literature.

A Theoretical Assessment of the Impacts of Poor Risk Management in the Construction Industry - A Case of Ethiopia

Yisakor S. Ferede, Nokulunga X. Mashwama and Didibhuku W. Thwala

Dept of Construction Management and Quantity Surveying, University of Johannesburg, Johannesburg, South Africa
SARChI in Sustainable Construction Management and Leadership in the Built Environment, Faculty of Engineering and the Built Environment, University of Johannesburg, Johannesburg, South Africa

The study examines previous literature on the impacts of poor risk management in construction industry, with specific aim of identifying the causes of poor implementation of risk management in construction projects. This is because the concept of risk management has attracted much attention in recent years and that researchers and research bodies, be it corporate or government that try to formulate remedies to poor risk management should begin with an understanding of the causes and impact of poor risk management. The totality of risk management in construction industries include the identification, measurement and prevention of all likelihoods of negative outcomes. The study is conducted with reference to existing theoretical literature, published and unpublished research. The study is mainly a literature review/survey on the cause and effects of poor risk management. One of the primary findings emanating from the study reveals that empirical studies have identified several important factors which causes poor risk management; such as project delays, project failure, reputational damages, and loss of profit, material scarcity, and inadequate project accountability amongst others. The study explores the causes and effects of poor risk management in construction projects and presents a robust background on the theories of poor risk management. This study will enable contractors, stakeholders and construction risk managers to achieve better result and quality projects.

Attributes Indicating Communication Influence on Leadership Development: A Delphi Selection Process

Murendeni Liphadzi, Clinton Aigbavboa and Didibhuku Thwala

123 SARChI in Sustainable Construction Management and Leadership in the Built Environment, Faculty of Engineering and the Built Environment, University of Johannesburg, South Africa, mliphadzi@uj.ac.za

Communication is an essential subject to the built environment and it generally presents special challenges. This is mainly true within the construction industry, were collaboration tends to be characterized by unfamiliar groups of people coming together for short periods before disbanding to their respective construction tasks, moreover the industry is dynamic and complex, which makes communication by industry leaders important. The study aimed at establishing the influence of different communication factors on leadership development in the construction industry. The study adopted the Delphi survey system of data collection to examine the study objective. Delphi experts (Construction specialists and researchers) were engendered from peer-reviewed conference proceedings and the South African construction industry professionals' database. The appraisal of different communication factors was done by identifying the influence of each communication factor on leadership development; these factors were measured between no influence and very high influence. Data collected were analyzed using mean item score and interquartile deviation. Of the different communication attributes evaluated, the ability for leaders to develop active listening skills had a high influence on developing communication attributes for leadership development in the construction industry. The article contributes to the frame of knowledge on leadership development and communication in the construction industry.

Keyords: communication, construction management, leadership

Barriers to ICT Adoption in Construction Revisited

Žiga Turk

University of Ljubljana, Slovenia, ziga.turk@fgg.uni-lj.si

The paper presents introduction to a study on the barriers to the implementation of information and communication technologies (ICT) in construction. In the study, we compared the ICT use in construction with some other industries - as reported in the literature and some industrial studies. We challenge the conventional wisdom that construction industry is not being rational in its choices to adopt (or not) various ICTs. We approached the issue from several methodological frameworks. In the paper we structure the reasons along the PESTEL framework. We examine each of the factors and suggest how they could be overcome. A survey has been designed and executed among the members of the Advisory Board of the EU Digiplace project. The results show that the industrial partners are less critical of the technology migration problems than researchers. The paper concludes that there is a need for a better way of deployment of and learning about new technologies that would benefit small and medium enterprises – the lag in productivity growth is largest there. This could be implemented in the form of industrial platforms in the context of the developments of the Industry 4.0.

Keywords: information and communication technology, technology adoption, construction platforms, construction industry

Compatibility of Personality and Productivity:
An Analysis of the Relationship with Construction Crews

Laura Florez[1], Phillip Armstrong[2] and Jean C. Cortissoz[3]

[1] *University College London, London, UK, l.florez@ucl.ac.uk*
[2] *Costain Group, Maidenhead, UK, phillip.armstrong@costain.com*
[3] *Universidad de los Andes, Bogotá, Colombia, j.cortiss@uniandes.edu.co*

The labor productivity of a crew depends on how efficiently workers are used in the construction process. Skills, capabilities, resources, and even personality affect the efficiency of the workers and may have an impact on the productivity of their crew. This paper illustrates how the personality profiles of the workers in a crew can be used to determine the relationship between compatibility of personality and productivity. Masons working in eight live construction projects completed the big five of personality to indicate their personality traits. Based on the personality traits, the compatibility of the crews was calculated. Productivity at the task-level was measured to determine the performance of the crews. Various statistical analyses are performed to establish the relationship between compatibility and crew productivity and the true value of the coefficient (and its likeliness). The results indicate that there is a high positive correlation between compatibility of personality and productivity at the task-level ($r_s = 0.758$). Results also indicate that in the worst case scenario, there is a moderate correlation between compatibility and productivity ($r_s > 0.3$; probability: 0.728). The implications of the relationship for managing crews in construction projects is discussed.

Keywords: compatibility, crew productivity, personality, productivity, statistical analysis

Construction Control Room for Project Monitoring and Control

Ali Ezzeddine[1], Lynn Shehab[1], Issam Srour[1] and William Power[2]

1   *American University of Beirut, Beirut, Lebanon*
2   *DPS Group, Little Island, Co. Cork, Ireland*

The world is a dynamic and ever-changing environment leading decision makers to believe that from plan to execution, unforeseen conditions will undoubtedly occur. The military is known to face unforeseen obstacles while conducting the operations forcing leaders to plan deviations. The construction sector is not far from the military in terms of planning and executing under uncertainty. One common problem the sector faces is delay in completing tasks and, consequently, projects. To mitigate the effects of uncertainty during operations, the military uses control rooms in order to deal with the worst when it occurs. Military control rooms provide a comfortable and collaborative environment for teams to proactively anticipate, highlight and mitigate potential plan deviations and to resolve emerging problems and constraints fast and efficiently. This paper introduces the concept of military operation rooms to construction by proposing a technology-based Construction Control Room (CCR) where several commercially available technologies are integrated into one comprehensive and inclusive framework for monitoring and controlling ongoing construction activities. It is a collaborative space where all relevant design and construction entities are present. Site data and requests are received, monitored, and processed directly in the control room for proactive and corrective measures. Moreover, this paper presents the elements of a simulation-based tool which outputs the required number of personnel in the CCR. Real project data is obtained from a live project that one of the authors worked on in Western Europe. Data is used to build a discrete-event simulation model that mimics the workflow in the real system in order to analyze the flow of information within the room, suggest the optimum number of members that should be present in each entity, and monitor the resource utilization of each entity. The results of the model show the potential of using such control rooms for enhancing construction project delivery.

Keywords: construction control room, discrete-event simulation, technology, lean construction

Development of a Risk Management Process for the Construction Sector

Dina Alfreahat[1] and Zoltán Sebestyén[2]

[1]   *Budapest University of Technology and Economics, Budapest, Hungary, alfreahat@mvt.bme.hu*
[2]   *Budapest University of Technology and Economics, Budapest, Hungary, sebestyen@mvt.bme.hu*

Projects are surrounded by a range of risks that can hinder their success, especially at the moment that characterized by the acceleration of economic growth, advanced technology, and intense competition. Construction projects have a special nature and one of their most important features is the project duration that may lead to changes in the conditions, which makes them contain multiple risks due to the long duration of the implementation period and the multiple stages that leads to increases in the probability of occurrence of the risks, which reflects negatively on the economics of construction. Therefore, risk management has emerged as a solution to control risks in a systematic and scientific way to avoid their negative effects.

This research aims to extend the processes of risk management from the perspective of construction to provide a framework for construction risk management processes. In this regard, the research highlighted the standard risk management processes based on PMBOK. Furthermore, we investigated the processes of construction risk management in the literature which lead to introduce two more processes besides the standard one, which are risk analysis verification and risk plan experimentation. This facilitated to develop the risk management outcomes in order to bring benefit to the organization. Additionally, we introduced some suggestions for construction risk management such as training and establishing a project risk information system in order to improve construction risk management. These suggestions shed more light on increasing the effectiveness of risk management through new ways.

Keywords: construction project, risk analysis, risk management, risk management process

Education's Impact on the Decline of Craft Workers in the United States Construction Industry

Scott W. Kramer, Carol Jayroe and April E. Simons

Auburn University, Auburn, Alabama, USA

As the number of craft workers in the United States has declined significantly in the past 20 years, various news articles and studies cite multiple reasons that have led to the decline. Perhaps the most significant impact is the evolution of technology. As technology has evolved, younger generations have not been exposed to the same opportunities as their parents and grandparents; therefore, they have not developed hands-on skills, causing a lack of interest in craft labor from an early age. If today's generation is not acquiring interests in these skills during their own time, has America's educational systems responded to this change by strengthening their vocational programs to maintain interest from the younger generation? For this study, data provided by the National Center for Education Statistics (NCES) was analyzed to determine the availability and interest in construction trade programs throughout the United States, to conclude if educational opportunities have impacted the recent decline in the construction trades.

Effective Project Management Principles and Strategies in Transportation Infrastructure Projects

Elnaz Safapour[1], Sharareh Kermanshachi[2] and Amirhosein Jafari[3]

[1] *Department of Civil Engineering, University of Texas at Arlington, Arlington, USA,*
   elnaz.safapour@mavs.uta.edu
[2] *Department of Civil Engineering, University of Texas at Arlington, Arlington, USA, (corresponding author),*
   sharareh.kermanshachi@uta.edu
[3] *Department of Civil Engineering, Louisiana State University, Louisiana, USA, ajafari1@lsu.edu*

Departments of Transportation (DOT) are experiencing unprecedented pressure to deliver projects on time and on budget. An obvious response to this pressure is to improve the project delivery process by adopting effective project management principles and strategies. The research team for this study investigated the DOT's implementation level of effective project management practices and strategies for transportation infrastructure projects by first performing a literature review to discover the project management strategies and practices historically used in transportation projects. Then, they designed a survey to identify the general project management practices implemented in the delivery process. They pilot tested the survey, distributed it to state transportation agencies via an online platform, and collected 96 completed surveys. The results revealed that team qualification was ranked the highest of the implementation level of strategies, and that environmental planning and quality management were ranked second and third. The outcomes of this study will help decision-makers and project managers in their assessments and selections of the most useful best practices for delivering an infrastructure transportation project on time, on budget, and with a high level of quality.

Keywords: tansportation infrastructure project, project management strategy, project management principle, design phase, construction phase

Effective Use of United States Foreign Aid to Fund Infrastructure Projects

Kevin McGuirk[1], Anoop Sattineni[2] and Wesley Collins[2]

[1] *United States Army Corps of Engineers, USA*
[2] *Auburn University, Auburn, USA*

Foreign aid is one of the tools the U.S. Government uses to promote stability and economic growth around the world. U.S. Foreign assistance to the region is currently guided by the U.S. Strategy for Central America which was announced in 2015. According to the U.S. Agency for International Development (USAID), average U.S. foreign aid to the Northern Triangle countries exceeded $400 million per year over the ten year period between 2008 and 2018. During this period approximately 10% of U.S foreign aid was used to fund infrastructure projects. Despite recent investment, the World Economic Forum ranks the infrastructure of the three countries in the Northern Triangle in the bottom half of all countries surveyed. With continued investment and unremarkable results over the past decade, it is useful to examine the efficiency of the investments and ensure available funding is effectively invested. USAID is the primary conduit for the distribution of US foreign aid. The United States Government works through several federal agencies outside the borders of the United States and much of this work is focused on security and military development in foreign countries. The U.S. Army Corps of Engineers (USACE) is one such agency and is currently managing overseas operations around the world. The main overseas mission of USACE offices appears to be in line with the development of military construction projects for foreign governments. In this paper, researchers examine the basic tenets of the proposed arrangements for the US to engage in funding infrastructure projects in foreign countries to alleviate un-employment related issues. The said funding also enhances the construction talent in countries receiving such funding. This is a qualitative research exploring the success of the proposed funding in the Norther Triangle region of Central America. Results from interviewing key personnel and literature review reveal that this opportunity can be improved to the benefit of all parties.

Keywords: foreign aid, infrastructure, Northern Triangle, USACE, USAID

Explicit Evaluation of Complexity in Construction and Real Estate Management

Wolfgang Eber

Technische Universität München, Lehrstuhl für Bauprozessmanagement, München, Germany, lbi@bv.tum.de

Complexity has become a major keyword when it comes to organization issues in Construction and Real Estate Management. Expressed via many different theoretical definitions, complexity in terms of management represents the part of organization which is simply not manageable. Therefore, reduction of complexity by separating a system into independent well-defined and well-controlled subsystems becomes a major task. However, since construction and real estate projects are becoming larger, encompassing higher volumes as well as higher numbers of participants and are nonetheless subjected to strongly limited time-frames and budgets on tight markets, efficient organization developed into the crucial issue to stand a competition successfully.

On this background, engineering naturally focuses on saving costly resources, where the explicit value of a single measure can easily be derived from the cost of the resource and the duration of the therewith reduced time floats. This leads to well-known concepts, e.g. just-in-time-delivery, where a system is optimized with respect to physical resources as well as virtual resources like storage space or reserve time. However, as this strategy clearly saves explicit local resources, concurrently the coupling of processes via the required availability of physical and virtual resources, ranging from pre-products to decisions, plans and responsibilities, is strongly increased and, thus, complexity is reintroduced to a significant degree.

This paper proposes an approach on the basis of Systems Theory providing an explicit measure to evaluate the increase of complexity in relation to possibly saved resources. Since cost of complexity are not given a priori but result from possible deviations, this article investigates the propagation of virtual uncertainties of real and abstract pre-products through a network of given complexity. On this basis, some general rules are derived allowing to maintain the balance between saving resources and the therewith increasing cost of the consequently rising complexity.

Keywords: complexity, systems theory, lean management, construction management, real estate management

Formal Modeling of Smart Contracts for Quality Acceptance in Construction

Da Sheng[1], Hanbin Luo[2] and Botao Zhong[3]

[1] *Huazhong University of Science & Technology, Wuhan, China, shengda@hust.edu.cn*
[2] *Huazhong University of Science & Technology, Wuhan, China, luohbcem@hust.edu.cn*
[3] *Huazhong University of Science & Technology, Wuhan, China, dadizhong@hust.edu.cn*

The coding and deployment of smart contracts in the construction industry are challenging because of the gap between the generality of existing modeling approaches for such contracts and the pertinence of business logic to construction management. This research proposes a formal model for smart contracts in the context of quality acceptance in the construction industry to reduce the threshold for applying smart contract technology. First, a conceptual scenario of smart contract-based quality acceptance in construction is analyzed. Second, a finite state machine-based model is proposed to formalize smart contracts for quality acceptance. Lastly, a Hyperledger-based case study is performed to demonstrate the performance of the proposed formal model. This study contributes to the industrial application of formal modeling approaches for smart contracts in the field of construction.

Keywords: blockchain, finite state machine, quality acceptance, quality management, smart contract

How Organization Will Enhance Benefits Realization by Using Innovation Project Managment and AI (Artificial Intilligence)

The Influence of Innovation Project Management on Project Success within Projects-Based Organizations

Tarek Tawfik[1], Jamila Al Maazmi[2] and Omran Al Shamsi[3]

[1] *Dubai Electricity and Water Authority, Dubai, United Arab Emirates, tarek.mohamed@dewa.gov.ae*
[2] *Dubai Electricity and Water Authority, Dubai, United Arab Emirates, Jamila.Juma@dewa.gov.ae*
[3] *Dubai Electricity and Water Authority, Dubai, United Arab Emirates, Omran.AlShamsi@dewa.gov.ae*

The importance role of innovation and technology is widely recognized in the corporate change, growth and profitability, but the main challenge is how to facilitate the innovative process and tools for practices and research, especially in project-based organizations. Where, conventional project management methods are oftentimes insufficient for managing innovation projects. In project-based firms, innovation is almost lost under the pre-determined scope and predicted environments of traditional project management. There is tremendous pressure on organization to innovate and the project managers are responsible to manage these innovation projects effectively. Therefore, innovation project management calls for providing the tools and technology (AI), perceptions, and metrics needed; in order to manage innovation projects successfully; helping PM's and stakeholders to identify problems in their organization, conceive elegant solutions, and, when necessary promote changes to their organizational culture. Thus, for this paper, authors attempt to conceptualize the innovation project management; to facilitate the innovation within project environment and to gain the ultimate corporate goals through their projects accomplishment.

Keywords: project-based organization, project management, innovation management, innovation project management, project success

Identifying Motivators and Challenges to BIM Implementation Among Facilities Managers in Johannesburg, South Africa

Chioma Okoro[1], Innocent Musonda and Andre Kruger

[1] Finance and Investment Management Department, College of Business and Economics, University of Johannesburg, South Africa, chiomao@uj.ac.za

[2] Construction Management and Quantity Surveying Department, School of Civil Engineering and the Built Environment, University of Johannesburg, South Africa, imusonda@uj.ac.za

[3] Finance and Investment Management Department, College of Business and Economics, University of Johannesburg, South Africa, akruger@uj.ac.za

The use of technology such as building information modelling (BIM) during the operational and management phase of a building helps to improve facilities and asset performance. However, the slow uptake of building information modelling (BIM) in the facilities and asset management industry diminishes the value derivable from properties and assets in general. The current study examines the motivation to adoption of BIM in the facilities and asset management industry and identifies barriers or challenges to BIM implementation in the sector. A field questionnaire survey was used to collect data among facilities management firms in Johannesburg South Africa. Empirical data from 17 participants were analysed to output frequencies on the challenges of BIM implementation. Findings revealed that competitive advantage, innovativeness, peer-push, as well as organisational image and objectives were motivators for adopting BIM in facilities management. The challenges of BIM implementation were mostly a lack of knowledge (trained personnel) on how to use BIM in facilities management, data management quality, lower data management standards (quality) at the operational stage, inadequate data provision for maintenance and management of facilities. Other issues included limited coordination or cooperation from team members and stakeholders on projects, absence of guidance on best practices to ensure performance optimisation and facilities management support using BIM, and financial commitment and infrastructure involved.

Keywords: assets, BIM, facilities, management, performance

Identifying the Factors Affecting Sustainability Cost Toward Optimization of the Project Selection Process

Dina Alfreahat and Zoltán Sebestyén

Budapest University of Technology and Economics, Budapest, Hungary, alfreahat@mvt.bme.hu

The dialogue that competes with politics and societal issues is becoming about sustainability. Sustainability has been drawing more attention now after many years of focusing solely on technology and development and neglecting the green aspect significantly, due to the growing resource constraints and the balanced requirement of environmental, economic, and social objectives. It is becoming increasingly important for all companies across all industries. The adoption of sustainability drives stakeholders to sustain their business success in the long-term. Therefore, they have to consider more factors than profit or loss when building their strategies and change their policies in the decision-making process to prevent environmental damages. Accordingly, decisions should be dictated according to the principle of sustainability, and the impact of these decisions should be planned for years and decades. According to the researchers and experts, the adoption of sustainability is facing two major obstacles, which are the increased cost of capital or perceived cost associated with sustainability and the lack of stakeholder's demand on sustainable projects due to the wrong perception that sustainability causes cost increase. Therefore, they can take sustainability costs as a primary concern in project selection. In this regard, the purpose of this study is to explore essential factors that have an impact on sustainability cost, which in turn, affects the project selection process, based on the theoretical backgrounds from the literature. To take the sustainability costs would help us to build a cost model, including the sustainability cost of the projects and their returns, which helps stakeholders to select the optimal sustainable project from several candidate projects in the project selection decision-making process. Thus, it can lead to an increase in the potential for creating win-win situations contributing to both stakeholders and sustainability value.

Implementation of the Common Vulnerability Scoring System to Assess the Cyber Vulnerability in Construction Projects

Bharadwaj Mantha[1] and Yeojin Jung[2] and <u>Borja Garcia de Soto</u>[3]

[1] *New York University Abu Dhabi (NYUAD), Abu Dhabi, United Arab Emirates, bmantha@nyu.edu*
[2] *New York University Abu Dhabi (NYUAD), Abu Dhabi, United Arab Emirates, yj1254@nyu.edu*
[3] *New York University Abu Dhabi (NYUAD), Abu Dhabi, United Arab Emirates, garcia.de.soto@nyu.edu*

The utilization of new technologies coupled with the digitization and automation of the construction industry (known as Construction 4.0) comes with many advantages. For example, it will make the Architecture Engineering and Construction (AEC) industry more connected, accessible, and transparent. However, the inherent nature of these connected systems will make construction networks more vulnerable and prone to cyberattacks. That will compromise not only the confidentiality of sensitive information but also the security of physical assets and project participants. With this background in mind, it is crucial to measure the security of construction networks. There are different systems to evaluate security vulnerabilities of a system, network, organization, or process; one of the most common is the Common Vulnerability Scoring System (CVSS), which provides a numerical score that reflects the severity of a given vulnerability based on specific identified metrics. This paper examines the application of CVSS to quantify and evaluate the vulnerability of project participants that can be used as the groundwork to determine the security vulnerability of construction networks. The objectives of this paper are 1) to examine the advantages and disadvantages of different scoring systems and their applicability to the AEC industry, 2) to systematically apply the identified system to determine scores for some of the most significant construction participants such as the owner, contractor, and worker. The proposed approach will help to assess the vulnerability of project participants and, eventually, the security level of construction networks.

Keywords: construction automation, CVSS, cybersecurity, security score, vulnerability assessment, vulnerability metrics

Improving But-For Delay Analysis and Concurrency Assessment

Moneer Bhih[1] and Tarek Hegazy[2]

[1]   University of Waterloo, Canada, Formerly, Univ. of Benghazi, mbhih@uwaterloo.ca
[2]   University of Waterloo, Waterloo, Canada, terek@uwaterloo.ca

But-For analysis is one of the popular techniques for apportioning the responsibility for project delays among the project parties (owner, contractor, and third party). Despite its acceptance by courts, one of its known drawbacks is that it produces conflicting results when adopting different party's viewpoints. Moreover, But-For analysis is not able to identify the concurrent delays caused by multiple parties. Despite some literature modifications to address those shortcomings, Modified But-For (MBF) analysis persistently does not consider event chronology and thus can produce wrong results. This paper thus discusses the concurrency assessment method of the MBF and introduces implementation improvements to divide the analysis into multiple windows to increase the analysis resolution, account for critical path fluctuations, and consider the chronology of different-party events, which is a requirement by recent delay analysis guidelines of professional bodies such as AACE and ASCE. A case study is used to show a detailed procedure for applying multiple-window MBF analysis to produce more accurate and repeatable delay analysis, considering concurrent delays.

Keywords: but-for, collapsed as-built, concurrent delay, construction, delay analysis

Integrated Application of BIM and Semantic Web in AEC Industry: A Literature Review

Zhiliang Ma [1], Xinglei Xiang [2] and Ren Yuan [3]

[1] Tsinghua University, Beijing, China, mazl@mail.tsinghua.edu.cn
[2] Tsinghua University, Beijing, China, xiangxl1996@163.com
[3] Tsinghua University, Beijing, China, renyuanc7@163.com

In the past decade, the application of both BIM and semantic web has been extensively studied in architecture, engineering and construction (AEC) industry. BIM provides a single database with rich building information and standard data exchange models, but there are still some limitations on consistency, adaptability and extensibility. Semantic web contributes to represent and integrate information formally, consistently and expansively, with the prerequisite of sufficient building information in AEC industry. On this basis, the integrated application of the two technologies is expected to complement each other and thus is receiving great attention. To clarify the status quo of the research field, literature retrieval was conducted and the result was summarized by analyzing the abstracts or the full papers when required in this paper. Firstly, the retrieved and screened papers were classified into two categories, i.e., (1) papers about BIM-based integrated application; (2) papers about semantic-web-based integrated application. Then, cluster analysis was carried out on both categories respectively to identify the key application areas, and detailed critical review was conducted to clarify the way to integrate semantic web and BIM to solve specific problems in those application areas. Consequently, three application areas under BIM-based integrated application were identified, i.e., BIM information representation and sharing based on IFC; BIM information translation from EXPRESS format to OWL format and BIM information integration with GIS information. Six application areas under semantic-web-based integrated application were recognized, i.e., facility management, cultural heritage conservation, energy management, aided design, construction management and cost estimation. This paper contributes to the knowledge body for taking advantage of the integration of BIM and semantic web.

Keywords: building information modelling (BIM), information management, integrated application, literature review, semantic web

Investigation of Possible Dominance of Factors Affecting Project Success

Zoltán Sebestyén, János Erdei and Dina Alfreahat

Budapest University of Technology and Economics, Budapest, Hungary, sebestyen@mvt.bme.hu

The bottom-line of project management is to produce the deliverables successfully. However, the various participants may interpret the term 'success' differently, and they assess the result of the project along with different indicators. A traditional, widespread, and clear set of indicators for the project managers are the time-cost constraints with the goal achieved in the right quality. Since the prediction and interpretation of success is a far more complex problem, researchers and experts have long been trying to answer the most critical questions relating to the success and failure of projects. Firstly, this paper provides a summary of how the traditional success approach evolved and how the researchers tried to extend the basic model and to grab its complexity. Secondly, the research goal is to formulate a research question on the possible dominance and effects of the factors. Finally, the authors develop the process and collect the possible mathematical-statistical tools supporting the previously mentioned goals. The founding of the research question in this article can lead to original assumptions, which highlights an area of research on the success that has not been explored so far. According to our intentions, this article lays the foundations for a thorough and comprehensive analysis for understanding better

Keywords: success criteria, success factor, perception of success

Knowledge Management and BIM Technology in Construction Project Management

Tomáš Mandičák[1] and Peter Mésároš[2]

[1] Technical University of Košice, Košice, Slovakia, tomas.mandficak@tuke.sk
[2] Technical University of Košice, Košice, Slovakia, peter.mesaros@tuke.sk

Knowledge systems and knowledge technologies are an important tool for resource efficiency in the management of construction projects. The exploitation of the knowledge systems is essential throughout the construction period, starting with designing and ending the building management. BIM technology represents another progressive technology in the management of construction projects. Last decades, it's a lot of information and assumption about the connection of BIM technology and knowledge-based technology in constriction project management. This research discusses the issue of knowledge management and uses BIM technology in constriction project management. The main aim of the research is to analyze the level of exploitation of BIM technology and knowledge-based technology in construction project management in selected countries in Europe.

Keywords: knowledge management, BIM technology, construction project management

Learning Curve for Improved Productivity in the South African Construction Industry

Somila Mhini, Nokulunga X. Mashwama, Didibhuku W. Thwala and Clinton O. Aigbavboa

Department of Construction Management and Quantity Surveying, University of Johannesburg , Johannesburg, South Africa
Sustainable Human Settlement and Construction Research Centre, Faculty of Engineering and the Built Environment, University of Johannesburg, Johannesburg, South Africa

The South African construction industry has battled with productivity for years despite being the key contributors to the economy of the country. This paper aims to remedy this problem by introducing the learning curve tool into the South African construction industry. The study sought to deduce the level of awareness of the learning curve and determine the benefits of adopting the learning curve tool in the South African construction industry. The Quantitative Methodology was adopted for this study and participation from construction professionals was obtained through a well-structured questionnaire. A total of 106 questionnaires were sent out and 62 were received back representing a response rate of 58.5%. The findings revealed that there is a moderate awareness of the learning curve tool in the South African construction industry. Additionally, the findings revealed that the workers would become familiar with their job and sharpen their skills which would result in a higher quality of construction work and the reduction of time taken to complete a task with reduced cost. The adoption of the learning curve tool in the South African construction industry offers a solution to a lasting problem of productivity in the industry. This study will enlighten construction professionals on the concept of the learning curve and the benefits of the learning curve.

Keywords: learning curve, productivity, South African construction industry (SACI), cost

Real Estate MSc Curriculum in the New Era of Artificial Intelligence

István Hajnal

Budapest University of Technology and Economics, Budapest, Hungary

In Real Estate industry a new era is approaching: Artificial Intelligence (AI) will re-design the map of the whole industry. As the real estate agency processes were moved to electronic platforms, and AI has significant role in brokerage and valuation, other Real Estate disciplines also will change dramatically, as Facility Management, Real Estate Development, Project Management and other related subjects. In this new upcoming era the academic education should accommodate the new approach and the AI-driven processes. In the paper, the Author overview those up-to-date changes and suggest a comprehensive curriculum for a Real Estate master-course which incorporates necessary skills and knowledge for the new generation of Real Estate professionals.

Keywords: real estate, education, artificial Intelligence

The Integration of Newly Graduated Construction Managers into the South African Construction Industry

Thulani Khoza[1], Mark Abrey[2] and <u>John Smallwood</u>[3]

[1] *Nelson Mandela University, Port Elizabeth, South Africa, khozathulani@gmail.com*
[2] *Nelson Mandela University, Port Elizabeth, South Africa, mhsabrey@yahoo.com*
[3] *Nelson Mandela University, Port Elizabeth, South Africa, john.smallwood@mandela.ac.za*

Anecdotal evidence indicates that newly graduated Construction Managers experience difficulty in terms of integrating into the construction industry.

Construction Managers (CMs) and Construction Project Managers (CPMs) registered with the South African Council for the Project and Construction Management Professions (SACPCMP) were surveyed by means of an online survey to determine the status quo with respect to newly graduated construction managers.

In terms of findings, graduates were rated: average to good / good in terms of overall performance, however, marginally so; marginally below average in terms of their performance relative to the functions of management work; highest relative to computer literacy, numeracy, and trust and honesty in terms of attributes / skills during probation; highest relative to computer literacy, numeracy, and written communication after probation; highest relative to construction technology, construction science, and research methodology in terms of knowledge areas, and highest relative to personal integrity in terms of ten core competencies.

Conclusions include: graduates are employable; challenges exist in terms of newly graduated Construction Managers, and tertiary built environment education must enhance graduates' attributes, knowledge, skills, core competencies, and emotional intelligence (EI).

Recommendations include: tertiary institutions should ensure that graduates are well versed and developed during their four-year study period; emphasis should be placed on developing core competencies and EI; employers should subject graduates to graduate training programmes; the interface between industry and tertiary education should be optimised through forums, and students should undertake construction-related vacation work and generic part-time work.

Keywords: construction management, graduates, integration, performance

Women in U.S. Construction Management Positions: A Qualitative Look at Motivations, Challenges and Considerations

Scott W. Kramer, Stephanie Woods and April E. Simons

Auburn University, Auburn, Alabama, USA

This research study considered why there are relatively so few women working in the United States construction management industry. The qualitative study examined the social and economic factors that influence women's career opportunities and choices, identified ways to interest girls and women in construction management, and determined how employers can better support women already working as construction managers. Five women who either are currently working in U.S. construction management positions, or who have worked in construction management, were interviewed using a qualitative research design. These structured-interviews focused on the women's motivations to join the construction industry, what barriers they encountered both in their education and on the job, and what suggestions they have for ways to support women either interested in or already participating in the U.S. construction industry.

Keywords: construction management, human resources, personnel management, women

Women's Representation in Federal Transportation Agencies: A Descriptive Analysis

Behzad Rouhanizadeh[1], Amirhosein Jafari[2] and Sharareh Kermanshachi[3]

[1] *University of Texas at Arlington, Arlington, USA, behzad.rouhanizadeh@mavs.uta.edu*
[2] *Louisiana State University, Baton Rouge, USA, ajafari1@lsu.edu*
[3] *University of Texas at Arlington, Arlington, USA, sharareh.kermanshachi@uta.edu*

Gender inequality in engineering career fields has been a source of social and economic disturbances for many years. In several cases, women are underrepresented, and disparities persist despite policies that have focused on initiatives to promote gender equality in the industry, and the inadequacy of tools for measuring and analyzing the imbalance confounds the problem. This study investigates women's underrepresentation in engineering careers from 2011-2017, by aggregating data from 17,889 demographic profiles of the U.S. Department of Transportation (USDOT) workforce. The objective of the study was to perform a descriptive analysis to (1) explore women's representation in the USDOT, and (2) discover the factors that can reduce or eliminate the low representation of female engineers and if there is any wage gap that exists between the genders. This includes the impact of factors such as job location, education level, type of appointment, job position and its importance, level of experience, and supervisory role of the employee. According to the outputs, women hold fewer high-level positions than men in the USDOT, but no significant gender-related wage inequality exists. The findings can help public and private organizations design legislative initiatives to achieve greater gender equality and assist employers of engineering organizations in moving toward a more gender-diverse working environment to reduce or eliminate gender inequality and its consequent challenges.

Keywords: women, underrepresentation, USDOT, transportation agencies, workforce, wage rate

Creative Scheduling in Construction

A Project Crashing Strategy Considering Contract Clauses and Quality Considerations: An Illustrative Example

Gul Polat[1], Firat Dogu Akin[2], Harun Turkoglu[3] and Atilla Damci[4]

[1] *Istanbul Technical University, Istanbul, Turkey, polatgu@itu.edu.tr*
[2] *Istanbul Technical University, Istanbul, Turkey, akinf@itu.edu.tr*
[3] *Istanbul Technical University, Istanbul, Turkey, hturkoglu@itu.edu.tr*
[4] *Istanbul Technical University, Istanbul, Turkey, damcia@itu.edu.tr*

Project crashing, a.k.a. project compressing or time-cost trade-off, is an important aspect of managing construction projects. Project crashing can be defined as the time-cost optimization technique, which aims to compress the total project duration with the least incremental cost. In real life problems, the quality is affected when some activities are crashed. This effect may be in a positive or negative way. In addition, there may be strict contract clauses regarding the project duration in terms of early finish bonus and penalty. In this study, a mathematical integer linear programming optimization model is developed using Visual Basic Programming Language integrated with Excel Solver add-in, in order to evaluate different strategies for project execution considering time, cost and quality concerns. Moreover, the developed model takes into account the relationship between crashing cost, early finish bonus, and penalty cost. The proposed model enables project managers to select the most appropriate project crashing strategy at the beginning of the project. An illustrative example is also presented in order to show how the proposed approach can be implemented in real cases.

Keywords: contract clauses, illustrative example, integer linear programming, project crashing, quality considerations

Accelerating the Execution of Construction Projects by Relocating Resources

Michał Tomczak[1] and Piotr Jaśkowski[2]

[1] Lublin University of Technology, Lublin, Poland, m.tomczak@pollub.pl
[2] Lublin University of Technology, Lublin, Poland, p.jaskowski@pollub.pl

Project managers strive to reduce the capital project execution times. Project owners typically insists on quick delivery for financial benefits of early occupation of the built facility (commercial projects), or for reducing public dissatisfaction caused by the works (public projects like road repairs). Construction and civil projects are notorious for delays due to both external and internal factors. The delays require action to be taken to make the project "back on tracks" and finish on time. Given a limited budget and the need for efficient use of resources, the problem of scheduling projects with short completion times is being addressed by a variety of ideas, such as letting non-critical construction processes to be suspended to free resources to more crucial ones, switching to faster but costly construction methods, or allowing changes in the process sequence. This paper presents a new idea on how to accelerate a construction project by relocating some of the workers from non-critical processes to support crews performing critical ones, and possibly by employing additional resources. The authors describe their idea in the form of a mixed-integer linear problem. The model facilitates finding an optimal schedule of processes allowing the relocation of some non-critical or subcontractor resources to support critical crews and meet the baseline execution deadline. A numerical example illustrates the merits of the proposed approach. In practice, the method presented can constitute a valuable tool used in the management of construction projects.

Keywords: construction project management, construction project scheduling, resource allocation, resource-constrained project scheduling problem, schedule optimization

An Enhanced Resource-Constrained Critical Path Method (eRCPM)

Diana M. Franco Duran[1] and Jesús M. de la Garza[2]

[1] Virginia Tech, Blacksburg, United States, dianitaf@vt.edu
[2] Clemson University, Clemson, United States, jdelaga@clemson.edu

The Resource-Constrained Critical Path Method (RCPM) identifies resource-dependent activity relationships (links) when mitigating a resource-supply demand problem. These resource links allow the identification of a continuous critical path and the calculation of correct float values. This paper presents the application of an Enhanced RCPM (eRCPM) in a progressed resource-constrained schedule.

The Enhanced RCPM 1) performs three different serial-based resource-constrained scheduling heuristics (one of those was developed by the authors of this study), 2) keeps and removes specific resource links in a progressed schedule before re-running the algorithm, and 3) selects a default schedule after evaluating some schedule characteristics. Additionally, an Enhanced RCPM system was developed and integrated with Primavera P6.

This system imports and reads data from a P6 project; performs the Enhanced RCPM; updates the P6 file; and puts the project back into the Primavera P6 database. From this updated schedule, users can get: 1) correct early and late CPM dates; 2) correct float values; 3) a continuous critical path; 4) the resources links that were added into the schedule, and 4) the amount of phantom float (float that does not exist) each activity had before adding the resource links into the schedule. The development of the eRCPM computerized system allows the identification of a continuous critical path, practically, in P6 resource-constrained schedules.

Comparison of Different Algorithms for Time Analysis for PDM Schedule Networks with Stretchable Activities

Levente Mályusz, Miklós Hajdu and Zoltán Vattai

Budapest University of Technology and Economics Budapest, Hungary

Well-known scheduling techniques for real life projects are CPM, PDM and their variants. In real life projects risk minimization of project duration is a corner stone problem which is often handled by Monte Carlo simulation. In this case project duration calculation is proceed many times with different activity durations, consequently this calculation is very time consuming. That is why the speed of the algorithms in this risk handling problem is crucial. In this paper we compare different scheduling algorithms for test projects. Our investigated network model is a variant of the PDM network where activity time is allowed to be stretchable. Since the frequently used project management software does not allow stretchable activity times, for comparison we use artificial projects.

Keywords: critical path method, precedence diagramming method, time analysis

Comparison of Different Scheduling Algorithms for Real Life Projects

Levente Mályusz[1], Miklós Hajdu[1,2] and Zoltán Vattai[1]

[1] *Budapest University of Technology and Economics, Hungary*
[2] *Chaoyang University of Technology, Taiwan*

Well-known scheduling techniques for real life projects are CPM, PDM and their variants. In real life projects risk minimization of project duration is a corner stone problem which is often handled by Monte Carlo simulation. In this case project duration calculation is proceed many times with different activity durations, consequently this calculation is very time consuming. That is why the speed of the algorithms in this risk handling problem is crucial. In this paper we compare different scheduling algorithms for real life projects. Our investigated network model is the most frequently used variant of the PDM network.

Keywords: critical path method, precedence diagramming method, time analysis

Construction Industry Perspective on Planning and Scheduling Content

Saeed Rokooei[1], Neil Pickavance[2], Alireza Shojaei[3] and Andrew Ross[4]

[1] Mississippi State University, Starkville, USA, srokooei@caad.msstate.edu
[2] Liverpool John Moores University, Liverpool, UK, N.M.Pickavance@2017.ljmu.ac.uk
[3] Mississippi State University, Starkville, USA, shojaei@caad.msstate.edu
[4] Liverpool John Moores University, Liverpool, UK, A.D.Ross@ljmu.ac.uk

This paper succinctly reports a study performed to explore planning and scheduling as the two key components of every project. Construction project managers devote a major portion of their daily time to develop, revise, and update their schedules. The same emphasis exists in construction education where the content is provided in one or two major courses through which students learn the basics and practice to develop project schedules with a high level of accuracy. To get inputs from industry and use them in the scheduling training process, a quantitative research method was utilized in the summer and fall 2019. The results indicated that scheduling as a major division has a strong presence in companies with different sizes, number of projects, and work experience. The results also indicated that different subcontractors have different levels of knowledge and competency in knowing and using time management tools. In addition, the results emphasized the importance of traditional time management techniques and methods. Better coordination between entities, more scheduling training for all, and team support of planners are reported as effective ways to improve the scheduling level. The outcomes help construction educators to revise their training material to correspond to the construction industry's needs.

Keywords: construction, education, planning, scheduling, time management

CPM Time Analysis for Defining Project Duration: Is It Still a Problem?

Miklós Hajdu[1,2] Levente Mályusz[1] and Zoltán Vattai[1]

[1]   Budapest University of Technology and Economics, Hungary
[2]   Chaoyang University of Technology, Taiwan

The deterministic time analysis is the prevailing algorithm in project planning/scheduling for defining the project duration and the early/late policies of activities. This algorithm, also called CPM analysis has been known for decades, yet different computer implementations sometimes result in different results for the same project, thus destroying the trust towards the tools, planners, and at the end the project management profession itself. This paper reviews some major issues regarding time analysis, explains their background, and also presents problems in the recent editions of some well-known tools. MS Project, Primavera, Synchro, SpiderProject and NetPoint were used for the purpose of this benchmark. The study compares the results of an example project consisting of three activities (one of them is a milestone). The salient findings show that after 60 years of the invention of network techniques, and three decades of desktop computer-based scheduling software, time analysis is still a problem. The conclusion of the study is that planners and clients cannot trust the results of the time analysis, and this calls for a standardization process led by professional bodies.

Keywords: CPM time analysis, milestone

Deep Learning Algorithms to Generate Activity Sequences Using Historical As-built Schedule Data

Hamed Alikhani[1], Chau Le[2] and H. David Jeong[3]

[1] Interdisciplinary Engineering, Texas A&M University, College Station, USA, hamedalikhani@tamu.edu
[2] Interdisciplinary Engineering, Texas A&M University, College Station, USA, chle@tamu.edu
[3] Department of Construction Science, Texas A&M University, College Station, USA, djeong@tamu.edu

Project schedule development requires having knowledge about the project's activities and the proper sequence of them. In traditional practice, arranging project activities in a feasible sequential order heavily relies on the project scheduler's practical experience. However, personal experience is limited and prone to include human errors. In this paper, a Deep Learning model is employed to be trained on historical project schedules to predict sequential activities. The proposed model uses a Bidirectional Long Short-Term Memory Recurrent Neural Networks that learns the activity predecessors in the forward direction and the activity successors in the backward direction. The model receives one or more activities and predicts subsequent and precedent activities in a sequential order that have the highest likelihood of occurrence in the historical data. The model is compared with a Sequential Pattern Mining technique that identifies the most probable sequential patterns of activities. The two methods are applied to as-built highway project schedules obtained from a highway agency in the U.S to compare the performance of the two methods. While the Sequential Pattern Mining model provides sequential patterns for certain activities, the Deep Learning model generates a back-tail and a front-tail of activities with any arbitrary length for to provide a more flexible support tool for project schedulers.

Keywords: Deep learning, LSTM, construction scheduling, sequence analysis, highway project schedules

Improving the Information Flow in the Construction Phase of a Construction Project

Matti Tauriainen[1] and Antti Leväniemi[2]

[1] *Lujatalo Oy, Espoo, Tampere University, Tampere, Finland, matti.tauriainen@luja.fi*
[2] *Lujatalo Oy, Espoo, Finland, antti.levaniemi@luja.fi*

In a company and project level it has been noticed that the fluent flow of information will be an essential part of streamlined processes. In the construction phase of a construction project, the information transfers between numerous parties, via different platforms and between people and systems. As the information field in the construction business is highly dispersed, managing the information flow within it is important in terms of efficient workflows.

The study focuses on the problems perceived in the flow of information and the methods of improving the information flow with Lean and Building Information Modeling (BIM) in the construction phase. The study consists of a literature research and an empirical section, which is conducted as a case study. The data collection methods used in the case study are interviews, documents and direct observations made by the researcher. The results of the case study are analyzed and compared with literature findings. There are three cases from different construction phases and altogether six site managers and engineers from the case company are interviewed.

The case study indicates that the element fabrication schedule and manufacturing status of prefabricated elements is prone to change during the project and thus cause a need for a change to the construction process and management. Therefore, it is beneficial that the latency of information regarding prefabricated elements is cut down to minutes instead of hours or even days. As a result, the information flow in the construction phase can be improved especially by 4D scheduling with the use of Last Planner System, the visualization of digital assembly and schedule information in BIM environment and the integration with the Enterprise Resource Planning (ERP) system of prefabrication suppliers.

Keywords: building information modeling, information flow, last planner, lean

Predicting Time Contingency in Construction Schedules for USACE Projects

Anoop Sattineni[1], Anil Miglani[2] and Lauren Redden[1]

[1]   *Auburn University, Auburn, USA*
[2]   *United States Army Corps of Engineers, Washington, USA*

'Time Contingency' in construction planning is an often overlooked aspect and little attention is devoted to it during contract negotiations. There is lot of research done on cost contingencies in construction. This is especially true in Army or DOD projects even where construction completion is very critical to the mission. However, little research exists in the way of contingencies for construction schedule delays. In this paper researchers attempt to find various reasons for delay in USACE projects. Number of days are added to the construction schedule for past projects is analyzed and later used in Monte Carlo Simulation to predict the contingency time that can be added to the projects. As such, the objectives of the research presented in this paper are to assess the factors that affect scheduling contingency and to develop a simple model that can be used in estimating the expected time contingency of a construction project. Data was collected from USACE database of 80 projects and found that 26 of those were delayed because of various reasons. A total of 40 different reasons of delay were found in those 26 projects researched. These 40 different reasons were further grouped into 7 major categories to create a simple model using @Risk and Monte Carlo Simulation to predict time contingency. The model predicted a 10% time contingency for USACE projects which was very close to the observed schedule delays on sample projects.

Keywords: contingency, Monte Carlo simulation, schedule delays, USACE

Project Crashing with Crash Duration Consumption Rate: An Illustrative Example

Harun Turkoglu[1], Gul Polat[2], Atilla Damci[3] and <u>Firat Dogu Akin</u>[4]

[1]   *Istanbul Technical University, Istanbul, Turkey, hturkoglu@itu.edu.tr*
[2]   *Istanbul Technical University, Istanbul, Turkey, polatgu@itu.edu.tr*
[3]   *Istanbul Technical University, Istanbul, Turkey, damcia@itu.edu.tr*
[4]   *Istanbul Technical University, Istanbul, Turkey, akinf@itu.edu.tr*

Completing on time, within the estimated budget and at the desired quality are three main constraints of construction projects. However, construction projects become nowadays more complex than ever, so they are subjected to uncertainties and changes throughout the project life cycles. These uncertainties and changes may lead to severe delays in project duration. Therefore, project managers desire to reduce the project duration without changing scope of the project. Crashing a project is an advanced project management strategy, which aims to achieve the maximum reduction in project duration with the minimum additional cost without changing the scope. However, project crashing is a difficult task and should be used if it is necessarily needed. This paper proposes a model that considers crash duration consumption rates of activities for solving the project crashing problem. The crash duration consumption rate is the percentage that is set to determine the maximum amount of crash duration that an activity can consume with safety margin. The proposed model enables the schedulers to assign crash duration consumption rates to each activity that can be used during the project crashing procedure. Having applied the proposed model, the Monte Carlo simulation is also performed to determine the probability of completion of the project at the latest in crashed project duration. The applicability of the proposed model is presented along with an illustrative example. The proposed model is supposed to minimize the likelihood of delays, while maintaining schedule flexibility. In addition, the proposed model provides schedulers a new perspective in solving project crashing problems.

Keywords: crash duration consumption rate, illustrative example, Monte Carlo simulation, project crashing

Project Planning by Modified Gauss S-Curve

Vladimir Križaić and Dražen Hranj

Polytechnic of Međimurje in Čakovec, Čakovec, Croatia, vkrizaic@mev.hr, dhranj@mev.hr

Planning is the prediction of the future erfrmed most often by a gantt chart as a graphical representation of the activity with respect to the temporal abscissa component. In addition to the activity ordinates, there is also a cash-flow or S-curve given by the one-dimensional nonlinear equation. Today, there is a growing demand for two-dimensional or 3D modeling, including 3D planning through a vector cummulative S-curve. Monitoring the distribution of the situation on formerly realized projects creates an image of certain model behaviour of the 3D S-curve defined by the modified Gaussian curve. By developing fifteen project plans from the buildingconstruction industry and from the construction project through the Microsoft project, the discrete S-curve connects to the modified Gaussian S-curve (MGSC). Analyses are made that indicate the equivalence of the S-curves of plans and realization, which defines the function of the parameters λkv and b in the variable of investment amounts of projects. Therefore, modeling and simulating a new Gaussian curve-modified method creates an nM model for project development with the ability to optimize plans and an S-curve future projects and adjusting online technology.

Keywords: planning, cash flow, 3D modeling, modified Gaussian S-curve, optimization

Workflow Optimization with Construction Scheduling Under a Lean Perspective

Marco A. Bragadin[1] and Kalle Kahkonen[2]

[1]   *Alma Mater Studiorum - University of Bologna, Bologna, Italy, marcoalvise.bragadin@unibo.it*
[2]   *Tampere University, Tampere, Finland, kalle.kahkonen@tuni.fi*

Construction scheduling produces the most important construction documents as they disclose the total project duration, project stages and times of work packages, activity costs per time period, logical sequence of activities and corresponding consequences for quality and safety. The production model displayed by the schedule should address Lean principles of production, mainly the reduction of waste created by idle time of crews due to a non-optimized workflow and takt-time planning. In a Lean Construction perspective, the project schedule should address the workflow of activities and of construction crews through the workspaces of the building. Location-Based Management System (LBMS) is a recent and innovative method that aims at planning and managing construction projects in a process-oriented way. This approach is based upon the Location Breakdown Structure (LBS), a hierarchical categorization of the workspaces where construction activities are performed by trades. As different trades need different types of workspaces, the LBS should be trade and time dependent. In an on-going research an improved scheduling method for construction operations has been developed, based on a CPM - Precedence Network plotted on a Resource–Space chart. Space Units of the project work are identified by a Location Breakdown Structure (LBS), and project activities are identified by two dimensions coordinate system based on Resources (i.e. construction crews) and working spaces (e.g. floors of a multi-storey building). Therefore the network model can be structured understanding resource and space constraints. Space Units can be modified in different stages of the execution according to trade – specific requirements, therefore creating a time-dependent LBS, and resource-based activity plotting can enhance workflow modeling through locations. Takt time of workflow in each space unit can be easily detected and optimized through balancing the duration of the sequenced activities of the space unit. The aim of the proposed approach is to increase the quality of the produced schedule by addressing Lean principles concerning work-flow optimization and takt-time detection and planning. The scheduling approach has been tested on a sample project.

Keywords: takt time, construction, lean construction, project schedule, Location Breakdown Structure

Sustainable Construction, Health and Safety

A Damage-Based Analysis of Rework in Reconstruction of Infrastructure Projects Due to Natural Disasters

Elnaz Safapour[1], Sharareh Kermanshachi[2] and Thahomina Jahan Nipa[3]

[1]   Department of Civil Engineering, University of Texas at Arlington, Arlington, USA,
     elnaz.safapour@mavs.uta.edu
[2]   Department of Civil Engineering, University of Texas at Arlington, Arlington, USA,
     sharareh.kermanshachi@uta.edu
[3]   Department of Civil Engineering, University of Texas at Arlington, Arlington, USA,
     thahomina.nipa@mavs.uta.edu

The number of reworks and their corresponding costs are usually much higher for reconstruction projects than for construction projects. Even though a significant amount of research has been conducted to identify the causes and factors of rework, none have been based on post-disaster reconstruction. Therefore, it is the aim of this study, is to identify and categorize the critical factors that initiate the rework and affect the cost of post-disaster reconstruction of transportation infrastructures (PRTs). To fulfill that goal, a survey of 46 questions was developed and distributed. Thirty (30) completed responses were collected from a group of respondents who were owners, program managers, project managers, and engineers with experience in working on a reconstruction project. The responses were analyzed statistically, and it was found that when the reconstruction of a transportation project is complex, the number and cost of reworks rise significantly. It was also found that the number of reworks is directly related to the level of damage to the infrastructure, which means that skilled and experienced project managers must be assigned to the project so that the fast decision-making process can be ensured to avoid the excessive amount of reworks. The findings of this study will help decision-makers and program managers prevent undue expenses and delays in the restoration of damaged infrastructure after natural disasters and hurricanes.

Keywords: cost of rework, level of damage, post-disaster reconstruction, reconstruction of transportation infrastructure

A Methodology for Risk Assessment and Management for SMR Nuclear Power Plant Hit by High Explosive Warheads

Igal M. Shohet[1], Sima Michal Elkabets[1], David Ornai[1], Yosef Kivity[1], Erez Gilad[2], Robert Levy[1], Gal Shany[1], Matan Levi-Tzedek[1], Barak Tavron[3] and Gabi Ben-Dor[4]

[1] *Department of Structural Engineering, Ben-Gurion University of the Negev, Beer Sheva, Israel*
[2] *Nuclear Engineering Unit, Ben-Gurion University of the Negev, Beer Sheva, Israel*
[3] *Planning Development and Technology Division, Israel Electric Corporation, Haifa, Israel*
[4] *Department of Mechanical Engineering, Ben-Gurion University of the Negev, Beer Sheva, Israel*

Within its 2050 energy plan, Israel examines the demographic implications of a Nuclear Power Plant (NPP) in Shivta Rogem site in the Negev. NPP would have a great contribution to the diversity and robustness of energy sources in Israel. A Small Modular Reactor (SMR) is designated to be safer than existing NPPs and will have better resistance to external hazards due to inherent passive safety features. This study develops a risk assessment methodology for a Nuclear Power Plant (NPP), in particular, SMR, to withstand a large conventional warhead explosion (GBU-28). The methodology comprises: hydro-dynamic simulations, validation of the dynamic simulations using numerical analysis compared to the simulations, risk analysis and damage assessment given the reference scenario of a detonation of a GBU-28 inside the underground water pool of a NuScale SMR. Discrete fragility curves were developed to evaluate the capacity of the SMR critical components. The overall probability of failure was assessed based on a Fault-Tree-Analysis (FTA). Results of the 3 m explosion from the reactor bay wall showed a displacement of 13 cm, breaching of the SMR bay wall and the water pool wall, and 12 cm deflection of the Containment Vessel (CNV). Sensitivity analyses of the uncertainty values were carried out by posting HCLPF (High Confidence Low Probability of Failure) values to the fragility curves. Combination of the results of the study with the failure criteria of NuScale for seismic hazards reveals that given the hazard scenario, core damage is expected accompanied by release of radioactive materials to the atmosphere. The study concludes that building the SMR in Israel will require adapted protective solutions. Future research may examine protective alternatives such as adding a reinforced concrete protecting layer or the possibility to set the SMR at a deeper underground elevation.

Keywords: explosions, fragility curves, resilience, risk management, SMR

A Socioeconomic-Based Analysis of Disaster Preparedness, Awareness and Education

Ronik Ketankumar Patel[1], Sharareh Kermanshachi[2] and Mostafa Namian[3]

[1] University of Texas at Arlington, Arlington, USA, ronikketankumar.patel@mavs.uta.edu
[2] University of Texas at Arlington, Arlington, USA, sharareh.kermanshachi@uta.edu
[3] East Carolina University, Greenville, USA, namianm19@ecu.edu

Students are one of the most vulnerable subgroups of the general population in terms of disaster preparedness and response; however, many universities still lack strategies and planning for disaster preparedness, mitigation, and response. This study investigated students' perceptions of disaster awareness and preparedness, based on two demographic characteristics: where they lived (on campus or off campus) and their ethnicity. To carry out this research, a comprehensive literature review was conducted on disaster education. Next, a structured survey was developed based on the factors studied in the literature review, and it was distributed to university students above the age of 18 with the help of an online assessment tool, Qualtrics. A total of 111 responses to the survey were collected, and the data collected were analyzed by performing descriptive and statistical analyses. After conducting the analyses, it was found that the perspectives of the students living on campus towards disaster risk reduction (DRR) education was significantly different from those living off campus. There were similar distinct differences linked to their area of living and ethnic backgrounds. It was further revealed that based on both their location and ethnic background, students have very different perspectives on the role of their friends, parents, and the university in keeping them safe during a disaster. The findings of this study will help policymakers assess existing disaster preparedness programs and will help faculty members and the academic staff develop and implement effective disaster preparedness courses and drills at the university, based on the characteristics of the students.

Keywords: disaster education, students' disaster preparedness, students' perception, disaster awareness

An Analysis on Safety Risk Judgment Patterns Towards Computer Vision Based Construction Safety Management

Chansik Park[1], Doyeop Lee[2] and Numan Khan[3]

[1] School of Architecture & Building Science, Chung-Ang University, South Korea, cpark@cau.ac.kr
[2] School of Architecture & Building Science, Chung-Ang University, South Korea, doyeop@cau.ac.kr
[3] School of Architecture & Building Science, Chung-Ang University, South Korea, numape@gmail.com

Due to dynamic and constantly changing nature of construction projects, the highest accident and fatality rate makes the industry infamous in mitigating hazardous safety risks and protecting workers at jobsites. Despite of enormous efforts and serious attention by government agencies and professional bodies, current safety management still relies on traditional manual approach by auditing and supervising safety rule compliance which are infrequent, inefficient and prone to error. With the advent of new emerging technologies such as BIM, VR/AR, AI, computer vision, and big data analytics, various tech-based solutions to help manage and reduce site risks has been introduced during the last decade. Computer vision technology, in particular, has been most attractive to site safety monitoring by academics and construction startups around the globe. However, literature review has revealed that the vision-based researches are limited to object detection such as workers' PPEs and machines to help subsidize the manual approach prototypically. The purpose of this study is to propose a wide-range applicability of computer vision technologies by investigating safety risk patterns. In doing so, entire safety rules and clauses described in the Korea Occupational Safety and Health Agency (KOSHA) regulations of construction sector is reviewed and analyzed with safety experts. Four main safety risk judgment patterns were found and grouped for various vision technology applications. The remaining clauses was classified into two different types. It is expected that the findings of this study would provide an insight to researchers and developers in construction safety domain.

Keywords: KOSHA Rules, Computer Vision, Safety rule compliance, safety risk correlation pattern, risk recognition, safety monitoring

Analysis of Cost Performance Indicators in Reconstruction Projects: A Comparative Study of Low vs High Level Damages

Elnaz Safapour[1], Sharareh Kermanshachi[2] and Thahomina Jahan Nipa[3]

[1] *Department of Civil Engineering, University of Texas at Arlington, Arlington, USA,*
   elnaz.safapour@mavs.uta.edu
[2] *Department of Civil Engineering, University of Texas at Arlington, Arlington, USA,*
   sharareh.kermanshachi@uta.edu
[3] *Department of Civil Engineering, University of Texas at Arlington, Arlington, USA,*
   thahomina.nipa@mavs.uta.edu

With the increase in frequency and intensity of natural disasters, the number of transportation infrastructures needing reconstruction is also increasing. Insufficient financial resources and cost overruns are among the major limitations that affect the reconstruction works of the transportation infrastructure after a disaster; however, there are few resources to help practitioners monitor the cost of reconstruction and keep it within the allocated budget. This study aims to provide a comprehensive list of the critical factors that affect the reconstruction cost (CFRC) of transportation infrastructures after a disaster, and to categorize them, based on the level of damage incurred. A survey was conducted to determine the importance of 30 potential CFRCs, and the survey results were statistically analyzed. It was found that effective coordination plays a critical role in completing a project within the budget limitations, a slow decision-making process slows the reconstruction efforts and increases the probability of cost overruns, and the reconstruction cost of transportation infrastructures with a high level of damage are dependent on more factors than infrastructures with a low level of damage. For example, when the damage level is low, fewer disruptions to traffic are necessary during the reconstruction than if the damage level is high. When the damage level is high, the likelihood of more traffic disturbance is greater, which has the potential to create unforeseen costs and/or cost overruns. The outcome of this paper will be of value to the authorities who are responsible for controlling budget overruns during post-disaster reconstruction projects.

Challenges in Post-Disaster Housing Reconstruction: Analysis of Urban vs. Rural Communities

Apurva Pamidimukkala[1], Sharareh Kermanshachi[2] and Elnaz Safapour[3]

[1] Department of Civil Engineering, University of Texas at Arlington, Arlington, USA,
apurva.pamidmukkala@mavs.uta.edu

[2] Department of Civil Engineering, University of Texas at Arlington, Arlington, USA,
sharareh.kermanshachi@uta.edu

[3] Department of Civil Engineering, University of Texas at Arlington, Arlington, USA,
elnaz.safapour@mavs.uta.edu

Reconstruction of safe and secure housing is commonly considered the most effective means of returning rural and urban communities affected by disasters to pre-disaster living conditions. In addition, the reconstruction process and the degree of its success greatly impacts the community's ability to work through the next disaster. The various challenges that the reconstruction process encounters have been identified, investigated, and analyzed in this study. After reviewing 177 articles in detail, approximately 30% of which pertained to reconstruction of houses after earthquakes, 54 challenges were identified and placed into four categories: general, physical, social, and economic. About 30% of the reviewed articles were studied the challenges of housing reconstruction after earthquake. In addition, the journal of Disaster received the highest frequency (37) among the reviewed papers in which the challenges of housing reconstruction after disaster in urban and rural communities were studied. This study succinctly assists decision-makers and project managers allocate needed resources effectively and improve the performance of post-disaster reconstruction of housing in both rural and urban areas.

Keywords: post-disaster recovery, housing, reconstruction, rural, communities

Critical Construction Work Items for Sustainable Hospitals

Claudia Valderrama-Ulloa[1], Pablo Canales[2] and Ximena Ferrada[3]

[1]   *Pontificia Universidad Católica de Chile, Santiago, Chile, c.valderrama@uc.cl*
[2]   *Ministerio de Salud, Santiago, Chile, pablo.canales@minsal.cl*
[3]   *Universidad del Desarrollo, Santiago, Chile, ximenaferrada@udd.cl*

Currently, the Chilean public health infrastructure presents significant advances in the implementation of sustainable design criteria, with the incorporation of these criteria in the architecture and speciality projects. However, it is possible to observe that during the construction phase of the project there are no standardized verification processes of the project guidelines in these aspects, which could affect the sustainable life cycle of these buildings. Errors in the execution of critical health infrastructure items have various consequences during their operation, such as excessive corrective maintenance, increased in public spending for additional energy requirements from the systems, or discomfort of building occupants (overheating or over-cooling problems). Besides, the technical inspection of public works in Chile focuses mainly on the administrative fulfilment of construction contracts rather than on the verification of the technical aspects of projects. This problem establishes the need to analyze the critical items that must be verified on-site to ensure that the sustainability criteria delivered during the design stage are executed correctly, allowing a sustainable operation of these buildings over time. Then, this research focused on determining what the critical items and activities that should be reviewed on-site, as well as on detecting the possible weaknesses of the project review process are. A survey to professionals involved in the design, construction and inspection of hospital infrastructure was applied. The results were analyzed using the AHP methodology, showing as critical items the thermal envelope (20%) and the thermal and ventilation installations (17%). At the activity level, there was no significant consensus on the most relevant to the review process. There are also differences in the vision of engineers and architects regarding some issues. Finally, the need to have technical regulations that provide procedures and control standards for each item, system and installation from early design phases was identified.

Keywords: public health infrastructure, sustainability, sustainable buildings

Designing Sustainable Gabion Houses for Haiti Using Local Resources

April E. Simons, Heath Barton[2] and Ryan Logan[3]

1   Auburn University, Auburn, USA, ellisap@auburn.edu
2   Auburn University, Auburn, USA, jhb0051@tigermail.auburn.edu
3   Auburn University, Auburn, USA, rel0035@tigermail.auburn.edu

Many concrete masonry unit (CMU) block homes have been constructed recently in Thoman, Haiti using volunteer labor under the supervision of But God Ministries. The average cost of construction is $5,000 per home and is dependent on availability and willingness of volunteer labor. Thoman's landscape is covered in loose rocks, largely due to dried up river beds. A sustainable home design which utilizes this abundantly available resource could drive down construction cost and reduce the need for volunteer labor. Gabion walls are wirework containers filled with rock or rubble. Though they are typically used in the construction of dams and retaining walls, they have successfully been used to construct other various structures including structural foundations (Liu, 2012), commercial construction (Conti, 2016) and residential applications in developing countries (Potangaroa, 2013). This research includes the physical construction of an L-shaped wall to determine the effectiveness and feasibility of constructing gabion homes in Thoman, Haiti. The physical wall model consists of a 2-foot wide by 6-inch deep concrete foundation, 8-foot tall wall cages of 10-gauge concrete reinforcing mesh with 6-inch by 6-inch openings, No. 1 aggregate wall infill, and stucco finish on both sides. The total length of wall is 16-feet, with one 10-foot leg and one 6-foot leg. Scaled models of three different roof structures were constructed and analyzed to determine which material systems would best serve the intended purpose for the gabion home design. The roof systems tested include wood frame, angle iron frame, and PVC frame, each of which was topped with corrugated metal roof panels. Two methods were tested for airflow which include corrugated plastic panels and mesh screens. The research findings suggest that chicken wire should be added to the proposed design to serve as a liner for the gabion baskets. The added wire helps secure smaller river rock and provides additional surface area for stucco adherence. The recommended cement to sand mixture for stucco was found to be 1:1. The angle iron framed roof proved to be the most effective of the three roof systems tested because of its availability, strength, and durability. Finally, the mesh screens were chosen to be the most effective roof ventilation method as it was shown to provide more airflow through the structure. Future research should analyze the strength and lifecycle of the final proposed design and evaluate alternate roof systems.

Keywords: gabion, rubble, house, sustainability

Digital Fabrication of Contemporary Structures in Architectural Design Optimization

Anna Stefańska[1] and Saurav Dixit[2]

[1]   *Department of Structure, Design, Construction and Technical Infrastructure, Faculty of Architecture, Warsaw University of Technology, Poland, anna.stefanska2@pw.edu.pl*
[2]   *RICS School of Built Environment, Amity University Noida, India, sauravarambol@gmail.com*

Trends in contemporary architecture are constantly changing the quality of engineering solutions through broadly understood optimization. The designers, as never before, are facing the possibility to adjust the material and manufacturing technology to desired aesthetic outcomes, by not only the material usage but also the self-organization of the optimization of the structure. The development of modern computational software and the ability to modeling structural forms in non-Euclidean geometry while using algorithms lead designers to new fields of designing and constructing. Parameterization of modeling tools and processes caused an increase in interest in bionic and biomimetic inspirations. It is expressed by imitation of the structure and behavior of living organisms. Such actions enabled the implementation of ideas as *forms follow energy* and *forms follow forces*. Analysis of the morphology of structural forms as well as generative modeling based on logical patterns taken from Nature are one of the contemporary tools of designing. Nowadays, the development of building technologies is strongly supported by digital techniques of manufacturing building elements, which has a significant impact on the architectural detail shaping. Geometrically complex forms are generated as non-modular elements; due to the rapid growth of digital fabrication (components with different shapes are made individually - cut out by CNC machine tools, printed, cast). with outstanding precision). A vital element of new technologies development is the search for new materials and the improvement of manufacturing methods at the same time. The article presents new tools and methods for the optimization of structural elements on selected examples.

Keywords: Architectural Design Optimization, digital fabrication, fabrication, generative design

Establishment of a Framework to Measure Disaster Preparedness: Development of Strategies to Enhance Disaster Preparedness Activities

Ronik Ketankumar Patel[1], Sharareh Kermanshachi[2] and Thahomina Jahan Nipa[3]

[1] University of Texas at Arlington, Arlington, USA, ronikketankumar.patel@mavs.uta.edu
[2] University of Texas at Arlington, Arlington, USA, sharareh.kermanshachi@uta.edu
[3] University of Texas at Arlington, Arlington, USA, thahomina.nipa@mavs.uta.edu

Despite disasters being extremely disruptive to campus life and affecting students both mentally and physically, college students are one of the most overlooked sub-groups in the community following a disaster. It is, therefore, crucial for disaster risk reduction (DRR) to be implemented in universities, where disaster preparedness, response, and mitigation strategies and programs are still lacking even though disaster awareness has increased. This study aims to investigate disaster awareness and preparedness of university students and develop a framework within which to measure the level of their disaster preparedness. To fulfill the objective of this study, a comprehensive literature review was conducted to understand how knowledgeable and prepared students are for disasters. The review provided the basis for the development of a comprehensive survey that was distributed through an online platform. After two follow-ups, 111 survey responses were collected and analyzed, both qualitatively and quantitatively. Based on the analysis, a framework was developed, linking the characteristics of students with different levels of DRR education. It was found that the students' perspectives of the responsibility of friends, parents, and university and/or government agencies to provide for their safety during a disaster are formed by personal characteristics (male or female, graduate or undergraduate, educated or uneducated about disaster preparedness, etc.). It was also observed that graduate and undergraduate students have significantly different opinions about the adequacy of the first aid boxes at their university, and students with prior disaster preparedness education believe that it is important for local communities to help educational systems implement DRR courses. The opinions of students with prior disaster preparedness education differ significantly from those without disaster preparedness education on whether DRR education should be mandatory. The findings of this study will contribute to the US educational system to effectively develop and implement DRR courses and will guide policymakers in their assessment of the universities' emergency preparedness policies.

Keywords: disaster-preparedness education, disaster preparedness framework, students' disaster preparedness

Health and Safety Challenges on South African Regional Public Sector Projects

Nomakhwezi Mafuya[1] and John Smallwood[2]

[1] Nelson Mandela University, Port Elizabeth, South Africa, nomakhwezi_mafuya@yahoo.com;
[2] Nelson Mandela University, Port Elizabeth, South Africa, john.smallwood@mandela.ac.za

The South African construction industry has a poor health and safety (H&S) record, and continues to be noted for H&S non-compliance, injuries, and fatalities.

The aim of the study reported on was to evolve a strategy to mitigate H&S non-compliance, injuries including fatalities, design originated hazards, and recurring H&S problems experienced on a provincial Department of Public Works' (DPW) projects.

The study adopted a quantitative approach and focused on seven school construction projects, and included, inter alia, construction project managers (CPMs) based in the provincial DPWs' project management department that were involved with the projects. The CPMs were surveyed using a self-administered questionnaire.

The study determined that inadequate H&S knowledge and awareness, inadequate H&S management and supervision on site, inadequate worker participation, inadequate H&S training, inadequate designer 'report', negligence, unsafe acts and conditions, H&S non-compliance, inadequate Safe Operating Procedures (SOPs) and Safe Working Procedures (SWPs), inadequate commitment of various project stakeholders, ignorance, and poor client H&S leadership are the primary causes of H&S non-compliance, injuries including fatalities, design originated hazards, and recurring H&S problems.

Recommendations include: H&S must be included as a project value; H&S must be integrated within the Department's internal project systems from project inception to project close out, and all stakeholders' H&S competencies must be enhanced.

Keywords: clients, health and safety, practices, value

Impact of Family Income on Public's Disaster Preparedness and Adoption of DRR Courses

Thahomina Jahan Nipa[1], Sharareh Kermanshachi[2] and Ronik Ketankumar Patel[3]

[1] *University of Texas at Arlington, Arlington, USA, thahomina.nipa@mavs.uta.edu*
[2] *University of Texas at Arlington, Arlington, USA, sharareh.kermanshachi@uta.edu*
[3] *University of Texas at Arlington, Arlington, USA, ronikketankumar.patel@mavs.uta.edu*

When disasters occur, they affect a community's educational institutions, yet students are still one of the most ignored groups of people when it comes to disaster preparedness. Demographic characteristics highly determine and influence the effects of a disaster; hence, when preparing for it, the students' demographic information should be considered. Little research exists in the literature that addresses the impacts of such characteristics on students' preparedness. Therefore, this study aims to identify the impacts of demographic information related to family income on students' perceptions of disaster preparedness and disaster risk reduction (DRR) education. To fulfill this goal, a survey was conducted, and 111 responses were collected. Statistical analysis revealed a several intriguing conclusions. It was found that all of the students, irrespective of their family income, realize the necessity of DRR education and are willing to take the course if it is offered. Family income comes into play, however, when the resources of the DRR courses are discussed. Students with different family incomes have different perceptions regarding phycological first aid training and knowledge of disaster medicine included in DRR courses. It was found that family income has a significant impact on students' awareness regarding emergency procedures and communication systems offered by the university, as well as on students' confidence in assisting the university with disaster management during a disaster. This study will help educational institutions and practitioners develop DRR resources that will be best suited for the students with certain demographic characteristics.

Keywords: disaster preparedness, family income, students' perception of DRR education

Impact of Natural Disasters on Construction Projects: Strategies to Prevent Cost and Schedule Overruns in Reconstruction Projects

Apurva Pamidimukkala[1], Sharareh Kermanshachi[2] and Sanjgna Karthick[3]

1   Department of Civil Engineering, University of Texas at Arlington, Arlington, USA,
    apurva.pamidmukkala@mavs.uta.edu
2   Department of Civil Engineering, University of Texas at Arlington,Arlington, USA,
    sharareh.kermanshachi@uta.edu
3   Department of Civil Engineering, University of Texas at Arlington, Arlington, USA,
    sanjgna.karthick@mavs.uta.edu

The number of natural catastrophic events has increased remarkably in recent decades, and the resulting challenges of construction projects have increased even more. It is imperative to recognize these challenges and employ suitable strategies to mitigate them to avoid project failures, which is the basis of this study. To become more knowledgeable about this subject, more than 100 scholarly articles, including peer-reviewed papers and other types of publications, were reviewed and a list of eleven challenges was developed. The next step was to identify the management strategies that could be applied to overcome the challenges. The outcomes from this study concisely help decision-makers and project managers allocate their resources wisely after a disaster, implement construction activities more efficiently, and achieve higher rates of productivity while reducing the consequences of disruptive events.

Is Virtual Reality Safety Training Making the Construction Industry Safer?

Jason B. Manning[1], Junshan Liu[2] and Lauren Redden[3]

1 Auburn University, Auburn, USA, jbm0086@auburn.edu
2 Auburn University, Auburn, USA, liujuns@auburn.edu
3 Auburn University, Auburn, USA, wybenlm@auburn.edu

The construction industry by nature is an unsafe environment to work in. It's a large industry that employs a lot of people and unfortunately experiences a large number of accident's each year. Construction companies invest a lot of money in safety training trying to educate their work forces. The primary types of training are instructor led, through training manuals and hands on. 80% of accidents happen due to human error. This statistic shows the conventional ways of training need improvements. Virtual Reality's popularity has exploded over the last decade and its use in the construction industry has increased mainly due to the use of 3D modeling for construction designs. Construction companies have also started using it as a safety training tool. It provides the ability to put a worker in an unsafe situation virtually for them to think through the process and come up with a solution. This paper is intended to review the research that has already been conducted on the topic of virtual reality use in the construction safety training industry. It will also perform a survey of construction contractors to determine if they have used or are planning to us virtual reality safety training.

Keywords: Virtual Reality, VR, BIM, 3D modeling, construction safety, training

Noise Reduction and Ventilation System:
A Design of a New Intelligent Window

Keming Ye[1] and Hanbin Luo[2]

[1] *Huazhong University of Science & Technology, Wuhan, China, 302618456@qq.com*
[2] *Huazhong University of Science & Technology, Wuhan, China, luohbcem@hust.edu.cn*

In order to enable people to have a more comfortable living environment, a new type of intelligent window has been invented to solve the problem that traditional windows cannot meet the people's need for noise reduction and natural ventilation simultaneously. This intelligent window system uses light and environment-friendly materials, and equips with circuit system which can control the hardware to achieve the optimal opening size by scientific calculation method and monitoring real-time environmental parameters through multi-factor sensors, so that users can get the best acoustic environment experience and air-breathing quality. This system can also consider the residents' different living environment and surrounding sound field conditions, and make personalized adjustment according to the individual sensitive interval of different environmental parameters. The system is also installed a laboratory to test the ventilation and noise reduction performance. The experimental data showed the noise reduction and ventilation system performance was effective, and it could avoid the interference caused by noise and airflow disturbance to residents.

Keywords: natural ventilation, noise reduction, self-adjusting system, sick building syndrome

Schedule Performance Analysis of Infrastructure Reconstruction Projects Due to Extreme Events

Elnaz Safapour[1], Sharareh Kermanshachi[2] and Thahomina Jahan Nipa[3]

[1] Department of Civil Engineering, University of Texas at Arlington, Arlington, USA,
elnaz.safapour@mavs.uta.edu

[2] Department of Civil Engineering, University of Texas at Arlington, Arlington, USA,
sharareh.kermanshachi@uta.edu

[3] Department of Civil Engineering, University of Texas at Arlington, Arlington, USA,
thahomina.nipa@mavs.uta.edu

Timely post-disaster reconstruction of transportation infrastructures is vital, as it affects the pace of the overall physical and economic recovery of the disaster-ravaged area. To ensure the completion of the project within the optimum amount of time, it is important to know what factors affect the duration of the project, but it is difficult to find a comprehensive list of those factors in the current literature. This study aims to fill that knowledge gap by identifying the factors that affect the timely reconstruction of transportation infrastructures (PRTs) following a natural disaster. A survey was developed and distributed to collect data for this study, and the responses were analyzed statistically. It was found that the possibility of schedule overruns increases with the levels of complexity and damage. Hurricanes in particular cause sudden shortages of resources (experts, suppliers, laborers, materials, and equipment) that reduce the productivity and increase the duration of reconstruction projects. The results of this study will help practitioners and engineers take steps to complete reconstruction projects within the estimated schedule.

Keywords: identification of factors, post-disaster reconstruction, reconstruction time, transportation infrastructure

Sleep Duration and Results of the Psychomotor Vigilance Test in Construction Workers: A Preliminary Study

Ximena Ferrada[1, 2], Silvia Barrios[3], Patricia Masalan[4], Solange Campos[5], Juan Carrillo[6], Yerko Molina[7]

[1] Universidad del Desarrollo, Santiago, Chile, ximenaferrada@udd.cl
[2] Pontificia Universidad Católica de Chile, Santiago, Chile, xferrada@uc.cl
[3] Pontificia Universidad Católica de Chile, Santiago, Chile, sbarrios@uc.cl
[4] Pontificia Universidad Católica de Chile, Santiago, Chile, mmasalan@uc.cl
[5] Pontificia Universidad Católica de Chile, Santiago, Chile, scamposr@uc.cl
[6] Unidad de Medicina Respiratoria, Hospital de Calama, Calama, Chile, jcaraz@gmail.com
[7] Universidad Adolfo Ibáñez, Santiago, Chile, ypmolina@uc.cl

The construction industry is known by its high rate of accidents. Among the different possible causes of this situation we could find lack of sleep and fatigue. Chronic sleep deprivation is a determining factor in the deterioration of vigilance and alert, and consequently a risk factor for occupational accidents. Fatigue is the answer of our organism to sustained physical and mental effort. Construction workers are prone to fatigue, since their work is characterized by heavy lifting and awkward work postures, so it is relevant to study it more thoroughly, especially regarding its association with sleep efficiency and quality. Regretfully, those topics have been very poorly studied in the construction industry. To understand better these phenomena and to propose strategies to mitigate it and contribute to the reduction of accidents in construction projects, the objective of this study was to understand if there is a relation among sleep duration and fatigue. We worked with 154 male construction workers from one Chilean construction company. To asses sleep quality we used the Pittsburgh Sleep Quality Index. One of their questions asked for average sleep hours in the last 4 weeks. To evaluate fatigue, we used a personal computer version of the Psychomotor Vigilance Test (PC-PVT) that measure alertness and vigilance. This 5-minute test was performed by construction workers on site in the morning. People was classified into groups according to self-reported sleep hours, namely: 7-9 hours (26%), 5-7 hours (61.7%) and <5 hours (12.3%). These results were compared for 3 variables (Mean Reaction Time, 10% faster and 10% slower) using an ANOVA test. Differences were found for Mean RT and Slowest10%, the difference being greater in the group that reported sleeping <5 hours, but without statistical significance. Studies with a greater number of subjects and measurements are required throughout the working day.

Keywords: construction workers, fatigue, sleep duration, vigilance

The Contribution of BMS Application Towards the Sustainability and Life Cycle Costs Optimization of Buildings: A Case of Public Utility Facilities in Poland

Krystyna Araszkiewicz[1], Patrycja Jakubowska[1] and Saurav Dixit[2]

[1] West Pomeranian University of Technology, Szczecin, Poland, krystyna.araszkiewicz@zut.edu.pl, patrycja.jakubowska@zut.edu.pl
[2] RICS School of Built Environment, Amity University Noida, India

BMS (Building Management System), i.e. the central building control, assumes integrated control of all building functions - from air conditioning and heating to lighting, access control and security issues. Properly designed BMS solutions improve the operation of the building service, allow for a quick reaction in case of emergency situations and significantly facilitate maintenance activities. Building automation systems also allow for data collection and analysis, which can be used among other things, to optimise energy and water consumption in buildings.

The aim of the paper is to provide and to discuss findings of the analysis of the impact of the BMS application in the city stadium design, which is an example of a public facility, on the possibility of controlling the life cycle costs of the facility under examination.

In the first step, on the basis of the design documentation and the stadium operation schedule prepared by the authors, the life cycle costs of the analysed facility were calculated in accordance with the methodology recommended by the Polish public procurement law with use of the SMART SPP calculation tool. The functional assumptions of the BMS designed for the stadium were taken into account. Then a change was introduced to the analysis at the input consisting in the simulation of BMS removal from the facility and then the introduction of the risk factor of human error on the part of the staff during the annual operation of the stadium in relation to the operation of the lighting system of the facility. The analysis is summarised by comparing the calculation results for both scenarios. The findings indicate the benefits of using BMS in facility management.

Keywords: BMS (building management system), life cycle costs analysis, sustainability, SDG, energy consumption, smart buildings

Towards Sustainability of Real Estate Development:
An Integrative Review of Smart City Planning Considerations

Chioma Okoro[1], Andre Kruger and Marno Booyens

[1] *Finance and Investment Management Department, College of Business and Economics, University of Johannesburg, South Africa, chiomao@uj.ac.za*

[2] *Finance and Investment Management Department, College of Business and Economics, University of Johannesburg, South Africa, akruger@uj.ac.za*

[3] *Finance and Investment Management Department, College of Business and Economics, University of Johannesburg, South Africa, marnob@uj.ac.za*

With the ever-increasing urban sprawl in African cities, more attention should be paid to the provision of real estate infrastructure to cater for the population. Ways to harness Africa's possibilities and leverage the opportunities available in the fourth industrial revolution, to diminish housing infrastructure backlogs, warrant consideration. The current study therefore aims to identify the factors that influence the sustainability of real estate developments in recent times, with attention to the planning considerations. An integrative review was conducted with literature from databases including Scopus, Google, Google Scholar, Publish or Perish, Academic Search Complete and Emerald. Synthesis was undertaken using thematic content analysis to identify themes on the factors influencing real estate developments and its sustainability. The distillation of literature revealed that institutional and economic factors were considered the most important factors, while developer's attitude and socio-cultural factors were the least occurring among the sampled literature. By establishing these factors, the current study provides important information for housing and construction stakeholders to be informed and guided in the planning and implementation of real estate development policies in order to provide for and sustain the needs of the current population and future generations given the need for smart cities.

Keywords: development, real estate, smart city, sustainability, urban housing

Visualization, Virtual Reality BIM and 3D printing for Design and Construction

A BIM-Based Conceptual Model to Manage Knowledge in Construction Design

Ahmed Al Sehrawy[1] and Omar Amoudi[2]

[1] School of Computing, Engineering and Built Environment, Glasgow Caledonian University, UK,
    ahmed.alsehrawy@gcu.ac.uk
[2] Department of Built & Natural Environment, Caledonian College of Engineering, Sultanate of Oman,
    omaramoudi@nu.edu.om

Managing knowledge had always captured the attention of researchers, since Plato's epistemology till now, where it is seen today as the most valuable asset of any organisation, and in a rapidly growing world as ours, the key to success is not perceived anymore as money, but mainly as knowledge. Construction is not different, where knowledge plays a vital role in its projects success, construction design phase in particular is one of the highest activities in terms of knowledge generation, however, designers still have got no clear process to manage knowledge efficiently. On the other hand, BIM or Building Information Modeling; a revolutionary framework that invaded construction market through the last decade, has a fundamental effect over the whole industry and over the way of how things are done, therefore, among the hundreds of applications and benefits of BIM, knowledge management could be one of them. This Paper attempts to fill that gap, by suggesting the use of BIM as a powerful tool to manage knowledge efficiently within the construction design activities to help in finally overcoming all limitations of the previous traditional knowledge management models, this is done through proposing a conceptual model that adds knowledge as an extra dimension to BIM, and which can capture knowledge generated during projects, assign it to the corresponding model building components, using the BIM parametric option, where it can be shared and easily recovered later when needed. New definitions are introduced through this paper and an illustrative hypothetical case study is conducted by the end of the study, to validate the proposed framework and demonstrate its effectiveness, benefits and expected limitations.

Keywords: BIM; knowledge management; construction design

A Comprehensive Map for Integrating Augmented Reality During the Construction Phase

Hala Nassereddine[1], Christian Schranz[2], Makram Bou Hatoum[3] and Harald Urban[4]

[1]   University of Kentucky, Lexington, USA, hala.nassereddine@uky.edu
[2]   Technical University of Vienna, Austria, christian.schranz@tuwien.ac.at
[3]   University of Kentucky, Lexington, USA, mbh.93@uky.edu
[4]   Technical University of Vienna, Austria, harald.urban@tuwien.ac.at

The construction industry has undergone a significant and radical transformation in its design and documentation process as it evolved from the days of the drafting board to today's Building Information Modeling (BIM) process. At each stop along that journey, gains were made in information density and exchange. However, for all the progress made thus far, the paradox of designing the 3D in 2D space remains. This paradox indicates that new visualization technologies are needed to leverage the use of information in construction. Augmented Reality (AR), a pillar of the fourth industrial revolution, is an emerging technology that has great potential to transform the construction industry. AR can be described as an information aggregator that allows the user to passively view displayed information, actively engage and interact with published content, and collaborate with others in real-time from remote locations. While AR holds the key to advance the construction industry, no research project has yet comprehensively investigated the holistic integration of AR in construction. The contribution of this paper to the body of knowledge is a comprehensive map that establishes a sound framework for specifying the appropriate integration of AR into the construction phase. The comprehensive map is based on the Task-Technology Fit theory, where 23 use-cases of AR in the construction phase are identified and outlined as a function of nine AR capabilities and 14 AR potential benefits. The AR use-cases, capabilities and potential benefits are first discussed in the paper. Then, two AR applications are explored where the underlying use-cases are discussed and mapped as a function of their corresponding AR capabilities and potential Benefits. These AR applications provide an example illustrating the concept behind the comprehensive map. Finally, the comprehensive map is developed to provide a holistic framework to understand the integration of AR into the construction phase.

Keywords: augmented reality, framework, taxonomy, task-technology fit, visualization

A Computer Vision-Based Approach to Classifying and Storing Image Data for Construction Safety Management

Zhitian Zhang and Hongling Guo

Department of Construction Management, Tsinghua University, Beijing, China

The safety issues on construction site have been a critical problem and has received increased attention. The safety management approaches based on computer vision provides more chances to rapidly identify the unsafe hazards and instantly alert. However, related research mainly focused on specific scenarios or tasks and therefore lack of holistic and systematic discussions. On the other hand, the storage and processing mechanism of the collected image data is not timely and efficient enough, so it's impossible for managers to quickly extract the required information. In order to better apply computer vision into practice, a classification and storage approach for site images based on computer vision is proposed. Firstly, this paper provides well-organized descriptions and classifications of the site hazards based on the survey results. Secondly, according to the literature review, sort out the current applications of the computer vision technology in construction safety management, and analyze the various types of site information it requires. Finally, the safety management requirements and on-site technical information are comprehensively processed to establish a framework to classify and store the site image. Then, we assessed the actual effects with this framework in conjunction with a case study. The results imply that the approach proposed promotes the application of computer vision from a holistic view and improves the efficiency in safety management.

Keywords: construction safety management, image data, computer vision, classification, storage

A Lightweight BIM-GIS Integration Method for Rural Building Design and Construction

Shuo Leng[1] and Zhen-Zhong Hu[1,2]

[1] Department of Civil Engineering, Tsinghua University, Beijing, China
[2] Shenzhen International Graduate School, Tsinghua University, Shenzhen, China,
   huzhenzhong@tsinghua.edu.cn

Building Information Model (BIM) and Geographic Information System (GIS) are both important data sources in the design and construction of buildings, and they have different emphasis on building information definition. A unified database that integrates BIM and GIS information is needed in many cases. However, most of the studies and applications of BIM-GIS integration are concentrated in urban buildings. Research on BIM-GIS integration in rural buildings is still rare. In fact, rural residences usually have different information characteristics with urban buildings. These characteristics need to be carefully considered to achieve effective information integration. A lightweight BIM-GIS integration method for rural building design and construction was proposed in this paper. The proposed method integrates BIM and GIS based on the Cesium platform, and realizes multi-scale lightweight algorithm based on the characteristics of rural houses. Based on a case study, the proposed method demonstrates its feasibility and efficiency in integrating BIM and GIS data. We believe it can assist with the design and construction of rural buildings.

Keywords: BIM, GIS, integration, lightweight algorithm, rural building

AEC Team Collaboration Efficiency in Remote 3D Coordination Meetings Using Immersive Virtual Reality

Bita Astaneh Asl[1] and Carrie Sturts Dossick[2]

[1] *University of Washington, Seattle, USA, astaneh@uw.edu*
[2] *University of Washington, Seattle, USA, cdossick@uw.edu*

Architecture, Engineering, and Construction (AEC) firms seek to employ technology tools for efficient collaboration to deliver high-quality and cost-efficient projects on time. There is an increasing demand for global projects that prevent team members from often co-locate for collaboration. As the information and communication technology progress, there is also less tendency for face-to-face meetings in local project teams to save the time spent for co-location. Building Information Modeling (BIM) supports AEC project stakeholders to communicate and exchange data in the 3D coordination process. In current remote BIM-based collaboration, BIMs are shared on a 2D screen while one team member has control over the view and the pointer and can create markup on the model. Virtual Reality (VR) is a technology that enables the users to be immersed inside the model and create markup together in a 360-degree environment that could address the gaps in current industry practices. This paper presents the results of a research study conducted to evaluate the team collaboration efficiency in remote immersive virtual 3D coordination meetings in comparison to BIM-based practices. A controlled experiment was designed to compare the performance of six teams with different AEC roles in resolving design conflicts in two platforms of BIM and VR. The research study results show that all teams spent less time in VR to come to a mutual understanding of the team decision in comparison to the BIM platform. The team who found the optimal design alternatives in both platforms had a significantly lower meeting duration in VR. Team members, on average, had a more accurate understanding of the team decision in VR. While VR supported team communication and improved some of the participants' performance, some team members were disoriented in the VR's 360-degree environment and could not follow the team when a markup was created.

Keywords: immersive virtual reality, building information modeling, remote collaboration, 3D coordination

BIM-Based Cost Management Practices in the Quebec's Construction Industry

Ritha Oumbé[1] and Conrad Boton[2]

[1] École de Technologie Supérieure, Montréal, Canada, ritha-edwige.oumbe-monteu.1@ens.etsmtl.ca
[2] École de Technologie Supérieure, Montréal, Canada, Conrad.Boton@etsmtl.ca

Construction projects are known for frequent cost overruns, due to different issues including the limitations of conventional cost management approaches. Building Information Modeling (BIM)supported cost management (5D BIM) consists in associating the cost variable with a BIM model in order to optimize the management of construction costs. Although several studies have been conducted in different countries to identify the benefits of, and barriers to, the implementation of 5D BIM, data on its implementation and associated practices in Quebec are missing. The objective of this study is therefore to present the general picture of the implementation of 5D BIM in the Quebec's construction industry. In order to achieve this objective, an in-depth literature review was conducted, and a questionnaire was developed and distributed to a sample of cost management specialists in the AEC industry in Quebec. The results suggest that that while 5D BIM is recognized to foster the production of better estimates, the automation of estimation is still far from being a reality. Excel is still the main tool for allocating costs to quantities extracted from BIM models and for estimates preparation. Thus, 5D BIM is mainly used for cost estimating, budgeting and cost control but much less for claims management.

Keywords: 5D BIM, construction cost management

BPMN 2.0 Modelling for the Management of the Inspection of Execution Processes in Construction

Alice Gardini[1], <u>Marco Alvise Bragadin</u>[1], Berardo Naticchia[2], Alessandro Carbonari[2] and Alessandra Corneli[2]

[1]   *Università di Bologna, Bologna, Italy*
[2]   *Università Politecnica delle Marche, Ancona, Italy*

Nowadays digitalization is a growing challenge for the whole construction sector. Therefore, the need of supportive tools and procedures is becoming increasingly urgent in each construction project step and particularly for project supervision in the execution phase. This is a primary requirement especially for the public sector, since the legislative framework is becoming more and more focused on this aspect, in Italy as well as in the European and international context.

A formalization of the inspection procedures of project management in the construction phase is proposed through Business Process Modelling and Notation (BPMN) 2.0 language. The first key aspect of this proposal is to assume a model-based approach, which allows a more coherent information management, in contrast with the traditional document-based one. The second aspect concerns process modeling. In fact, the proposed method is based on processes, instead of BIM – based federated object-oriented models. Construction processes are modelled so that they can generate and feed the federated models themselves. In addition to this, Business Process Modelling and Notation can be used to create a collection of different procedures involved in the inspection management for construction projects. Also, BPMN model will allow an automatic feeding of an inspection management support system which will be developed in future studies, that will offer the full traceability of the procedures and the delivery of the quality certification of products. The case study of the inspection of ready-mix concrete cast-in-place process is analyzed and discussed.

Keywords: BIM, BPMN 2.0, digitalization, inspection of execution, process management

Effects of Virtual Reality's Immersive Environment and Markup Tool Capabilities on 3D Coordination Efficiency

Bita Astaneh Asl[1] and Carrie Sturts Dossick[2]

[1] *University of Washington, Seattle, USA, astaneh@uw.edu*
[2] *University of Washington, Seattle, USA, cdossick@uw.edu*

Although Building Information Modeling (BIM) has automated the 3D coordination process using the clash detective tool and finding field conflicts by comparing 3D models of building systems, it still requires the project team to communicate the conflicts to resolve. Project team members discuss the complex clashes in 3D coordination meetings. However, most of the issues are communicated asynchronously by sending documents electronically. In current BIM-based practices, annotations are created by drawing markup on the 2D screenshots of the model with comments added by text. Virtual Reality (VR) provides an immersive environment and allows users to draw markup in the 360-degree environment and communicate verbally. This paper presents the results of a research study that evaluates VR's immersive environment and markup tool capabilities on asynchronous 3D coordination communication efficiency. Two controlled experiments were designed to study (1) the effects of the VR's immersive environment on the user's understanding of the model and the relevance of building systems to each other as well as model recall, and (2) the efficiency of markup tool to communicate building system conflicts and resolutions. The experiment results revealed that exploring the model while being immersed in the VR environment provided a better understanding and recall of the building systems to the users in comparison to exploring it with BIM on the desktop screen. Moreover, most of the participants preferred VR's markup tool over BIM's to understand the 3D coordination annotations.

Keywords: immersive virtual reality, building information modeling, clash detection, 3D coordination, MEP

Evaluating the Effectiveness of Virtual Reality Construction Safety Training and Lessons Learned

Jeffrey Kim, Peesadech Zornnetr, Soundarya Korlapati, Nikolay Sargsyan, Satish Akula, Xin Wei and Cheryl D. Seals

Auburn University, Auburn, Alabama, USA

Virtual reality (VR) is often used as a training tool and research widely supports successful student performance in assessment scores when VR training tools are used. Experiential learning mimicked in virtual simulations has been found to significantly improve student's retention of new topics. However, some construction related topics do not improve when using VR. This study involved the creation of a construction excavation safety program that was administered using a VR headset. The researchers piloted the VR safety simulation as a controlled experiment to evaluate the effectiveness of VR reinforced learning as compared to presentation slides that are traditionally used for learning. A significant improvement was not evident in the results. The researchers undertook a further examination of elements of the virtual simulation to ascertain potential areas for improvement that could be used in future iterations of this study. The examination found that the participant's interactions with elements of the virtual simulation were essential as perceived by the participants. Furthermore, the study found that while realism was not a mandatory requirement for the VR simulation, the participant's interactions with characters in the VR training program did have some perceived negative impact. Additionally, motion (walking) within the VR simulation was a significant distractor for the participants. Considering these challenges, the researchers present their findings in this paper as a precautionary guide for further development of similar VR training tools.

Integrated Design Review Methodology for Critical Facilities Management and Maintenance

Igal M. Shohet[1,2], Kun-Chi Wang[2] and Sheng-Han Tung[2]

[1] *Department of Structural Engineering, Ben-Gurion University of the Negev, Beer Sheva, Israel*
[2] *Department of Construction Engineering, Chaoyang University of Technology, Taiwan*

Critical facilities are expected to provide continuous performance in standard service conditions and in extreme events in particular. Continuity of performance is determined by the design redundancy, robustness and resilience. A framework for Integrated BIM based service life design review developed for planning of critical facilities. The framework aims at the execution of the design, construction, and commissioning of projects with whole life performance, operation, and costs planning. The methodology follows two phases: (I) Service life planning and (II) Design review. Service life planning is carried out through four stages: (1) Definition of the service regime; (2) Service Life Prediction of the building components; (3) Performance planning, and (4) Service Life Agreement. Design review (DR) is carried out for four building systems: structural safety and integrity, exterior envelope, interior finishing, and exterior infrastructures; and six electro-mechanical systems: Electric and power supply system, Water supply and sanitary, HVAC, Fire Protection, Elevators, and Communication and low voltage systems. DR follows four principles: (1) Durability; (2) Techno-economic service life planning; (3) Maintainability; and (4) Minimization of the Life Cycle Costs (LCC). A Design Review matrix developed for automation of the DR process: the DR matrix is composed of four leading key factors. Key leading factors are Durability, Maintainability, Service Life Planning and Design Guidelines. An integrated public-hospitality case study carried out and presented.

Keywords: BIM, briefing, critical facilities, maintenance, performance

92

Transforming the AEC Industry: A Model-Centric Approach

Hala Nassereddine[1], Mahmoud El Jazzar[2] and Melanie Piskernik[3]

[1]   University of Kentucky, Lexington, USA, hala.nassereddine@uky.edu
[2]   University of Kentucky, Lexington, USA, meljazzar@uky.edu
[3]   Technical University of Vienna, Vienna, Austria, melanie.piskernik@tuwien.ac.at

The increased complexity of construction projects requires the involvement of a wide range of organizations throughout the project lifecycle – from conceptual planning to decommissioning. Construction project teams, therefore, differ from teams in other industries as they comprise individuals who are employed by organizations that conduct different businesses. These many separate organizations working together in a close harmony over the duration of the project is fundamental to the overall business of construction. Project success relies heavily on the management of the flow of information among players and access to the right information is vital to efficiently perform the work. Therefore, an efficient information access and effective information exchange methods internally and externally with other organizations needs to be achieved. The model-centric approach introduces a unique solution to solve the problems with the information jungle, inconsistency, and disintegration associated with the traditional document-centric approach. As such, a coherent use of information management is required to merge, co-manage, and semantically connect the information and artifacts generated throughout the project phases. Adopting a model-centric approach creates a single point of truth that centralizes information and facilitates access to it. A transformation plan is needed to outline the shift of the construction from document-centric to model-centric. This paper proposes a strategy to support the model-centric transformation of the Architecture, Engineering, and Construction (AEC) industry. Five strategic objectives are outlined and discussed in this paper highlighting considerations that need to be made to enable this transformation. This study describes the "what" necessary to enable and support a model-centric AEC industry.

Keywords: BIM, MBSE, model-centric, system engineering, technology shift

Authors' index