Book of Abstracts
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KEYNOTE ABSTRACTS

KEYNOTE LECTURES

Industry 4.0 paradigm for building design & construction

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This keynote provides results and case studies in innovation from actual work undertaken in collaboration with industry partners in Architecture, Engineering, and Construction (AEC). Scientific advances and innovative technologies in the sector are key to shaping the changes emerging as a result of Industry 4.0. Mainstream Building Information Management (BIM) is seen as a vehicle for addressing issues such as industry fragmentation, value-driven solutions, decision-making, client engagement, and design/process flow; however, advanced simulation, computer vision, Internet of Things (IoT), blockchain, machine learning, deep learning, and linked data all provide immense opportunities for dealing with these challenges and can provide evidenced-based innovative solutions not seen before. These technologies are perceived as the "true" enablers of future practice, but only recently has the AEC sector recognised terms such as "golden key" and "golden thread" as part of BIM processes and workflows.This lecture builds on the success of a number of initiatives and projects by the authors, which include seminal findings from the literature, research and development, and practice-based solutions produced for industry. It presents these findings through real projects and case studies developed by the authors and reports on how these technologies made a real-world impact.

This keynote builds on the success of several initiatives and projects at Teesside University and practice-based solutions produced for industry. It presents these findings through real projects and case studies on how these technologies made a real-world impact.

The contents are developed around these overarching themes:

- BIM and AEC Design and Optimisation: Application of Artificial Intelligence in Design
- BIM and XR as Advanced Visualisation and Simulation Tools
- Design Informatics and Advancements in BIM Authoring
- Green Building Assessment: Emerging Design Support Tools
- Computer Vision and Image Processing for Expediting Project Management and Operations
- Blockchain, Big Data, and IoT for Facilitated Project Management
- BIM Strategies and Leveraged Solutions

This keynote is a timely and relevant synthesis of a number of cogent subjects underpinning the paradigm shift needed for the AEC industry and is essential reading for all involved in the sector.

KEYNOTE LECTURES

Opportunities and challenges of using Pre-Fabricated Pre-Finished Volumetric Construction (PPVC) for high-rise construction

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Singapore has been continually striving to improve productivity in the construction industry. In 2015, the Building and Construction Authority (BCA) rolled out the 2nd Construction Productivity Roadmap to push the industry to adopt game-changing technologies and the adoption of innovative building methods. One of which is Design for Manufacturing and Assembly (DfMA) which include Pre-Fabricated Pre-Finished Volumetric Construction (PPVC). PPVC has been encouraged and even stipulated in government land sale which leads to more projects and taller buildings adopting such construction techniques. While there are benefits from this construction technique for example higher efficiency, reduced manpower on site, better construction quality, there are also many challenges which include procurement, higher cost, intellectual property protection, safety in lifting, tighter tolerances etc.

This paper looks into the various opportunities and challenges in the use of PPVC for high-rise construction. Some projects are used for the illustration. There are many lessons learnt and improvements made as the technology is used more.

Cybersecurity in a digital construction environment

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The modernization of the AEC industry includes new technologies such as building information modeling (BIM) and common data environments (CDEs) that increase the efficiency of construction tasks and make the industry more connected. It also facilitates the convergence of information technologies (IT) (e.g., digital data storage, generative design) and operational technologies (OT) (e.g., 3D printing, Internet of Things (IoT)). As a result, connectivity and collaboration in construction projects are reinforced, ultimately improving the efficiency, sustainability, resilience, and productivity of our built environment. These are all great things for a sector that is finding automation as a solution to address productivity issues. However, this increased connectivity (e.g., the use of digital twins) opens the door to significant vulnerabilities, which can influence the different stakeholders in an industry unaware of the cybersecurity implications of such digital transformation.

KEYNOTE LECTURES

Behind the scenes: An insight into the development of an award-winning cultural project

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The Liget Budapest Project is Europe's largest cultural project, in which the Hungarian government is creating a new museum district by revitalizing the continent's oldest public park. Among the many cultural buildings that have been completed, the Hungarian House of Music, with its unique appearance, has become an icon of the Museum Quarter. The building, designed by Sou Fuyimoto Architects and built by Hungarian contractors, has won numerous international awards:

a) Winner of the Grand Jury Prize at the MIPIM AWARDS in Cannes on March 17.

b) Winner of the World's Best Use of Music in Real Estate Development Award at the American Music Cities Awards on September 23, 2020

c) Named by CNN and the World Architecture Community as one of the top ten most anticipated new architecture projects of 2021.

The project manager - the presenter - was awarded Project Manager of the Year in Hungary and will represent the country in the IPMA Project Manager of the Year competition.

Behind the stunning final result is the project team, whose work, struggles and problems during the project are little known to the public. During the pre-conference tour, participants will be given a tour of the building by the project manager, while the keynote presentation will give the project manager a behind-the-scenes look at project management.

AUTOMATION AND ROBOTICS FOR CONSTRUCTION

An automated semantic segmentation-free approach to point cloud scene understanding in construction

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It has been long shown that deep learning methods need voluminous training data to automatically process point clouds and develop accurate as-built construction models. On the other hand, conventional semantic segmentation of point clouds can be used but requires significant time and manual effort. In construction, public and private Building Information Model (BIM) databases are available as information source and can facilitate semantic registration and enrichment. Therefore, this paper takes the initial steps and advances the Derivative-Free Optimization-based (DFO) approach by automatically recognizing 3D objects from point clouds using available BIM data and registering the correlated semantic information to each detected object using geometry and color features. More specifically, the proposed framework takes the as-designed BIM models and point clouds as input, samples as-designed models, and registers information as a log text file to the generated point cloud by minimizing the Mean Squared Error (MSE) value using geometry and color features. In order to validate the proposed framework, preliminary experiments were conducted on an office point cloud taken from the Stanford 2D-3D dataset. Results highlighted the potential of the proposed DFO approach in making good use of available BIM resources to efficiently process point clouds and generate accurate and semantically enriched as-built models.

AUTOMATION AND ROBOTICS FOR CONSTRUCTION

Automation of construction production using the DSP method

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Keywords: DSP cod method, cyber system technology, modeling standardization Bill of Quantities and Bid

Mechanical engineering and industrial production are developing at an unimaginable speed with digital renaissance technology. Construction technology lags behind it, but software has been introduced into operating systems. However, the effect of digital and information technology is not very effective. The key problem is the obsolescence of the standardization and standardization of construction processes. Therefore, the dynamic structural programming (DSP) method for construction products is proposed. It is the trend of today's cyber system technology of any technological production. By combining the DSP method with Modified Gaussian S Curves (MGSC), a probabilistic mathematical iteration management of the operating system of construction products is created. This is how construction operative production fits into today's trend of modeling and simulating construction processes.

Automated classification and coding for BIM components based on applicable big data

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Keywords: Building information modeling; classification and coding; association rule mining algorithm

For the application of BIM technology, BIM models play a vital role in transferring and sharing building information. BIM models represent the building information through the attributes of components, such as walls and slabs, and the relationship between the components. Among all the BIM components' attributes, classification and coding attribute is essential to retrieve the building information in a quick way. However, in practice, the BIM models that are prepared by using a BIM authoring tool cannot ensure complete and correct classification and coding attribute when they are transferred into the format of another tool. Besides, BIM models prepared by using 3D reconstruction technology also lack the classification and coding attribute. Missing or incorrect classification and coding attribute of BIM components impedes the fully exploitation of BIM model greatly. To solve the problem, this paper proposes an automated classification and coding method for BIM components based on a batch of BIM models with components labeled with key features and type, which can be obtained from the big data of the BIM models that have been correctly used. In the method, the association rule mining algorithm is used to establish the classification and coding rules for BIM components based on the labeled component dataset. Then, for any BIM component, an algorithm based on credibility reasoning is used to execute the rules and obtain its classification and coding attribute. In this way, the classification and coding attribute can be determined for any BIM component according to any given standard. The method is validated by developing a prototype based on Autodesk Revit and by using a batch of BIM models, and 92.7% precision is achieved in the test case. This approach contributes to the classification of BIM components in a quick way.

Conceptual design using BIM of ultra-high-speed construction system assuming emergency situations

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The Japanese construction production system has aimed to achieve a high degree of balance between high Q: quality, low C: cost, appropriate construction D: duration, S: safety assurance, and reduction of E: environmental impact in project results. Against the background of low economic growth and low interest rates after the bursting of the bubble economy, the Japanese client did not strongly demand "UHCS: ultra-high-speed construction system," which is the purpose of this research theme. However, if the QCSE satisfies the required standard, it is obvious that the introduction of UHSCS that realizes early recovery of funds will increase the value of the project. In addition, it goes without saying that reducing time, which is a parameter for amount of labor, material, and indirect costs, is effective in improving productivity, which the Japanese construction industry is currently working on. During the recent spread of COVID-19, those of us involved in construction watched helplessly as lives and health were lost due to the lack of medical facilities. In Wuhan city, China, a medical facility with 1,000 beds is said to have started operating 10 days after the site was prepared. In China, which is undergoing economic growth and has high financing costs, there was a strong need for UHSCS for hotels and offices. Based on the current situation, it is necessary to review UHSCS as another form of building production. The international architectural society has a social mission to prepare for the occurrence of similar pandemics and disasters such as earthquakes directly hitting the Tokyo metropolitan area that are predicted to occur in the future. This research utilizes the excellent construction elemental technology of Japanese industry, BIM, IoT, SCM and robotics, and presents a conceptual design of an UHSCS based on thorough standardization and labor-saving construction.

AUTOMATION AND ROBOTICS FOR CONSTRUCTION

Deep reinforcement learning driven autonomous flight UAV for construction progress monitoring

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Recent unmanned aerial vehicles (UAVs) are gradually gearing up for a transition toward automated progress monitoring in construction. For its successful application in dynamic (i.e. changing over time) construction sites, UAVs are required to have a substantial level of autonomy. In other words, UAVs should have the ability to accomplish planned missions in unexpected situations without human intervention. To ensure this level of autonomy, this paper proposes an improved deep proximal policy optimization (DPPO) algorithm which is aiming for path-following control problems. Customized reward functions are designed for minimizing the traveling time of UAVs without any collision with obstacles for automated progress monitoring. We realized training and testing of DPPO in a virtual environment with aid of Unity machine learning agents (ML-agents). Results found that DPPO can reduce 10% of traveling time and 50% of collision cases compared with heuristic search algorithms such as genetic algorithm and particle swarm optimization. Through this, we know that self-driving UAVs using reinforcement learning are highly likely to be used for monitoring work progress at dynamic construction sites.

DesignTracking: track and replay BIM-based design process

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Among different phases of the life cycle of a building or facility, design is of the utmost importance to ensure safety, efficiency and sustainability of the building or facility. How to control and improve design quality and efficiency has been explored for years, and more studies emerged with the popularization of Building Information Modelling (BIM). However, most of them focused on the extraction of design behaviors, while paid less attention to how a design is formed. Therefore, this study proposes an approach to tracking and replaying the BIM-based design process by integrating data logging and 4D visualization techniques. First of all, potential design behaviors and procedures are analyzed and extracted by observing how a designer designs a BIM model. Meanwhile, required data for logging design process is defined and relevant method to collect these data is developed based on the APIs of BIM software. Then, strategies on how to visualize different design procedures are designed and implemented via 4D visualization. Finally, a prototype system is developed based on Autodesk Revit and validated through case study. Result shows that the proposed approach enables intuitively and interactively review of the design process, and makes it easier to understand design behaviors and even identify potential pitfalls, thus improving the design efficiency and quality.

Developing a digital twin on a university campus to support efficient and sustainable buildings

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This study presents a case study for the proof of concept of developing and integrating a digital twin for an open floor-plan office space in a university campus to assess the real-time monitoring of different elements, including temperature, humidity and occupancy. The system uses various weather sensors and a camera feed as input to a computer vision algorithm to detect (near) real-time occupancy. The goal is to use this platform to provide real-time information about ambient and occupancy information that users and facility managers can use to make buildings more efficient and sustainable by considering users' involvement and feedback.

AUTOMATION AND ROBOTICS FOR CONSTRUCTION

Implementation of wireless and sensing technologies in highway projects: A SWOT approach

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Keywords: Construction; Asset Management; Departments of Transportation; Highway Projects; Technology

The demand for safe, reliable, and higher-quality transportation and infrastructure systems often increases the complexity of constructing and maintaining highway projects and pressures Departments of Transportation (DOTs) to finish projects on tighter schedules and stricter budgets. Such complexities are necessitating the use of technologies when constructing and maintaining transportation assets, notably wireless and sensing technologies. For the last few years, DOTs' use of wireless and sensing technologies has been on the rise, with numerous research efforts aiming to explore applications and investigate case studies. Thus, this study buildings on the existing body of knowledge to develop a holistic Strengths Weaknesses Opportunities Threats (SWOT) framework that aims to comprehensively understand the implementation of eight wireless and sensing technologies in highway projects including barcodes and readers, Radio Frequency Identification, e-ticketing, Ground Penetrating Radar, Unmanned Aerial Systems or Vehicles, Light Detection and Ranging, Geographic Information System, and Global Positioning System or Global Navigation Satellite System. The SWOT framework was developed in a survey and distributed to subject matter experts. Results from the survey provided comprehensive insights on the strengths of using the technologies in the project's construction and asset management phases, the weaknesses that these technologies may face, the opportunities that they provide DOTs with, and the threats that the DOTs may need to overcome for successful implementation.

Options of automated surveys for maintenance monitoring services of heritage buildings

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Maintenance monitoring is a key factor in the economic preservation of heritage buildings. Maintenance monitoring services are supporting the responsible staff in their preservation tasks and keeping the heritage buildings and sites continuously in a proper condition. Regular monitoring is an important, but time-consuming activity which needs a relevant amount of human workhour to be conducted properly. Automated survey methods are developed worldwide, to help the work of various professional research staff to investigate the state of different structures of the heritage buildings, however, these automated surveys are usually executed individually, not as integrated parts of the maintenance management systems. In this paper, the options of automation methods are analyzed regarding the various regular tasks of the monitoring staff, and suggestions are made to reduce human activities and to support the monitoring staff with fixed IoT and/or mobile (robotic) survey units at the maintenance monitoring service activities.

AUTOMATION AND ROBOTICS FOR CONSTRUCTION

Simulation-based optimization of path planning of camera-equipped UAV considering activities on construction site

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Automated progress monitoring from construction sites using cameras has been proposed in recent years. However, collecting images or videos using fixed or pan-tilt-zoom cameras is still limited by the inability to adapt to the dynamic construction environment. Therefore, considerable attention has been paid to using camera-equipped unmanned aerial vehicles (UAVs), which provide mobility to the camera over dynamic construction sites. Previous studies in this area proposed methods for capturing the as-built BIM model by using structure from motion (SFM). However, data collection of construction activities of workers and equipment using camera-equipped UAVs has not been discussed before.

This paper proposes a method to perform simulation-based optimization of path planning for camera equipped UAVs to allow automated and effective data collection of construction activities based on a high 4DLOD as-planned BIM, which includes a detailed micro-schedule and the corresponding workspaces. This method can identify the most informative views of the workspaces and the optimal path of data capturing using simulation-based optimization. The proposed method considers the following requirements and constraints: (1) The field of view of the camera during the path should allow data collection of multiple dynamic targets on the site considering the locations of their activities at specific times, (2) The visibility of the targets should be maximized considering the importance level and occlusions according to the 4D BIM model, (3) The path length of the UAV should be minimized to collect the most important spatiotemporal data of activities at different areas, and (4) The computer vision requirements (e.g., overlap rate and the angle of view) should be considered. A case study is developed to demonstrate the feasibility of the proposed method.

Using ChatGPT to solve a PDM network with FSO relationships

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Keywords Precedence Diagramming Method, time analysis, Artificial Intelligence, ChatGPT

Construction management professors, like educators in other disciplines, cannot ignore the rise of artificial intelligence. ChatGPT is one of the best-known AI applications available to the public for free or for a relatively small fee. ChatGPT is mostly used for essay writing, but students are pushing the boundaries and trying to solve more and more problems with AI. In this thesis, we investigate whether ChatGPT can solve a simple time analysis problem on a PDM schedule that contains only FS0 logical connections. The result of the research is that in the case where the network contains only FS0 connections, ChatGPT can be trained to correctly perform the first phase of time analysis, but it is not guaranteed that the new knowledge will be remembered and applied in the next chat. However, this does not mean that this will not change in the short term, and other users may benefit from the new knowledge generated in each conversation. This article was written on 1 June 2023 using ChatGPT version 4.

Unmanned Aerial systems for safety monitoring in construction: Effect on safety performance

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Keywords: agent-based modeling, construction safety, safety performance, unmanned aerial system (UAS).

Despite recent improvement in the area of construction safety, the construction industry remains one of the major contributors to the number of work-related injuries and fatalities. Unsafe site conditions and unsafe behavior by workers are the two main reasons behind construction accidents and accordingly these two factors should be continuously monitored. The application of unmanned aerial systems (UAS) for safety monitoring is currently gaining attention in the construction industry. However, the actual long-term effect of the use of such a system on the safety performance of a construction site is still unknown and scarcely discussed in the literature. The objective of this study is to devise an agent-based modeling tool to examine the improvement in the safety performance of a construction site when using a UAS for safety inspection. Safety performance is measured using three types of indicators: the incident rate which is a lagging indicator, and the safety behavior and hazards reported which are leading indicators. Moreover, the safety performance is explored under various scenarios reflecting important features of the project. For instance, the effect of the level of site risk and the initial attitude of workers towards safety on the proposed system is evaluated. The results show that during one year, the safety behavior of workers progressively and significantly improves and eventually becomes steady. A total decrease of 13.61% is found in the unsafe behavior of workers. Moreover, the calculated mean incident rate at the end of this year is 0.63 significantly lower than the incident rate of nonfatal occupational injuries in the construction industry in 2021 which was 2.7. Finally, it is found that 79% of hazards are detected using the UAS. However, the performance shows better results in projects with high levels of risk, and in projects where the initial safety culture is weak. The study contribution lies in providing safety managers and practitioners with a preliminary idea about the practical benefits of drones when used for safety monitoring, as well as the chance to understand, based on the nature of the project, whether employing the UAS can add value to their system.

CREATIVE CONSTRUCTION TECHNOLOGY AND MATERIALS

A decentralized mobile-based morning assembly application for construction sites with GPS-assistance technology and intuitive UI/UX

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Keywords: Construction, Construction Management, GPS, Mobile application, Morning Assembly

Morning Assembly in construction sites in Japan is an age-old practice that is influenced by tradition. One or more managers conduct this assembly by physically gathering construction workers in a designated place to relay information regarding tasks, safety, disasters, emergencies, Work Progress and many more. Typically, a bulletin board has been in use for this type of assembly. However, these assemblies are usually crowded, unmanaged and time-consuming. Besides this, workers are also less likely to pay full attention to the speaker due to the chaotic nature of the assembly. These assemblies can also be a ground for spreading infectious diseases like COVID-19 and others. Hence, with the aim of improving the overall assembly experience for both management and workers side, we propose an application that helps to conduct assemblies in a decentralized and secure manner. With this application, managers can conduct assembly and broadcast information directly to the worker's smartphone and hence eliminating the crowded and unmanaged nature of assemblies. This application uses the GPS location of the site and the registered worker's smartphone as an identification pair – which is then used to identify which worker is physically available inside which site. Once the worker is within the allowed range of the site, as determined by GPS data, information like site detail, disaster, and safety declaration of the current site along with images and videos is broadcasted to the worker. Site information is simply not broadcasted to devices located outside of the site range and designated time to avoid information leakage. Keeping workers' IT literacy in mind, the app is provided with a simple yet intuitive UI/UX to navigate through and gather assembly information. This novel application was tested in multiple construction sites on which it has helped to increase the productivity of managers and workers significantly.

An assembled and interlocking lunar base and its structural analysis during and after construction

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Keywords: lunar base, interlocking arch structure, finite element method, structural analysis.

Establishing a base on the lunar surface has become a new goal for space powers and even all humankind to explore the moon. However, the extreme environment and the lack of resources pose many challenges to the construction project. In this paper, an assembled and interlocking mixed structure was designed. The sintered lunar regolith can be used to build the load-bearing arch structure and the foundation structure, which are assembled by interlocking modules to facilitate construction on the lunar surface. An independent inflatable structure is needed inside the arch structure to ensure the air pressure environment suitable for human survival. The structure is covered with a 3m-thick lunar regolith layer to withstand large temperature fluctuations, intense radiation, and occasional micrometeorite impact. The main mechanical advantage of this structure is that each component is used to bear the load that it is best able to resist. The load-bearing arch structure and the foundation structure can be assembled and constructed with only 6 types of modules. Besides, the modules are self-supporting so that they can be assembled without support during construction. Subsequently, the finite element method was used to analyze the stress state during and after construction. In addition, the temperature field of the structure under the extreme temperature environment on the lunar surface was analyzed. The results showed that this lunar base structure is feasible, but the optimization design needs to be carried out at the module joint because it will produce stress concentration. This study provides a scheme for the construction of human lunar bases.
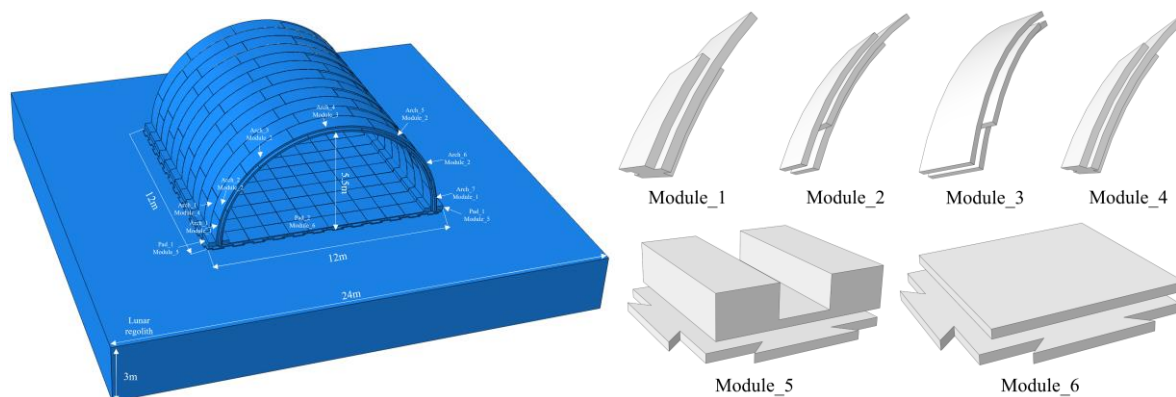
(a)   (b)

Fig. 1. (a) Structural scheme of arch structure and foundation structure of the lunar base, (b) interlocking assembly modules.

Analysis and measures to improve the efficiency of building information modelling in cost estimates

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Keywords: Building Information Modelling, Cost estimates and Calculations.

Building Information Models, BIM, and information in these models have been responsible for an "industrial revolution" in the construction industry, but there has not been the same focus on BIM in the early stages, like using it in cost estimation and calculations, also called 5D-BIM. Our research question is: "What are the advantages and disadvantages of using BIM in the calculation phase, and what measures can make this more efficient and user friendly." Information was first obtained by examining cost estimation programs used in a larger construction company in Norway. Secondly a survey was sent out to employees in the construction industry, where the respondents were asked to assess and explain their relationship with BIM and cost estimation. The results revealed that there is a lack of competence and training for those who use BIM-models for cost estimation. Secondly It has been identified that BIM-models used to calculations is not detailed enough. Integration of cost estimation earlier in the project development would have more influence on choices and solutions. The conclusion is that cost estimation has to be more efficient in the interaction with BIM, which includes implementation of stricter requirements for BIM-models used for dynamic calculations, skills has to be raised, and calculations should be involved earlier in the projects, and the public sector should be involved more to propose measures.

Configuration of 3D model segmentation configuration of object division function to improve the usability of the design 3D model in the construction stage

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Keywords: activity unit, building information modeling, construction stage, 3D model division, 4D system.

The 3D model created during the design stage is useful in managing the interference between elements of a structure. However, in most cases, the activity concept of the construction stage is not considered. As a result, the 3D model from the design stage must often be divided into activity units and re-modeled in order to be used in the construction stage, which reduces the reusability of the original 3D model created in the design stage. Therefore, if there is a function that can be conveniently divided into construction activity units while maintaining the attribute information of the 3D model, the usability of the 3D model created in the design stage can be increased through the construction stage. Commercial CAD software like Dynamo has a 3D model division function, but its method of use is somewhat complicated and requires additional software besides the 4D system to use the divided model for 4D simulation in the construction stage.

The authors present a methodology and module that can easily divide the 3D model into activity units by introducing the concept of a new bounding box, after importing the model into the 4D system. This made it possible to divide the 3D model and simulate the activity units of the divided model using only the 4D system without the need for separate CAD software. The divided model within the 4D system is applied to the 4D simulation for both pre- and post-division models to verify the usability in the construction stage. This division function is expected to improve the use of 3D models in the construction stage as it allows for direct division of design stage 3D models into activity units within the 4D system and simultaneous simulation.

CREATIVE CONSTRUCTION TECHNOLOGY AND MATERIALS

Creative modification of epoxy resins

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Keywords: Epoxy resin, epoxy based composite, mineral powders, composites properties.

Epoxy resins are a well-known and widely used building material. Most often in construction, they are used as top layers of layered elements. An example of such an application are floors in which the underlay is made of a cement composite and the top layer is made of epoxy resin. Despite many advantages, such as high chemical resistance, high water resistance, epoxy resins can still be improved by various types of additives in the form of crushed rock fractions, small-sized building materials, parts of plant origin and others. This article presents the results of research in the form of comparative analyzes of the use of feldspar-quartz, limestone, granite and basalt flours as fillers for epoxy resins. The basic physico-mechanical properties of the composites created in this way will be determined and their suitability for use in the construction industry will be assessed.

Impact of circulating fluidized bed fly ash on strength development of self-compacting concrete

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Keywords: compressive strength, fly ash, self-compacting concrete

The use of self-compacting concrete (SCC) instead of traditional vibrated concrete has many advantages, which are most evident through the increased efficiency of SCC concrete under the influence of the environment. However, its use requires careful planning of concrete works and careful optimization of concrete mix design. SCC usually includes large amount of fine particles which ensure cohesiveness of the mixture and provide enough excess paste which is necessary for achieving adequate flow properties. When pulverized coal fly ash is used as a fine mineral additive, its spherical particles reduce water demand, and slow pozzolanic reactions reduce permeability and this leads to increased durability. Nowadays, pulverized coal combustion technology is being replaced by combustion in a circulating fluidized bed (CFB), which is characterized by lower energy consumption. Circulating fluidized bed fly ash (CFBFA) particles are irregularly shaped and differ in chemical composition from pulverized coal fly ash. In this paper the possibility of designing SCC with the addition of CFBFA is being investigated. So, SCC mixes with different amounts of CFBFA were designed and its properties in the fresh state were tested using slump-flow, J-ring and L-box measurements. Compressive strength was tested in the period from 2 days to 90 days to evaluate the effect of CFBFA on strength development.

Novel developments to precast bridge girder technology by the BME-ZÁÉV research cooperation

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To strengthen cooperation between academic research and economy, the Competence Center on Safety Science and Technology has been established at BME in 2021 with financial support by the National Research, Development and Innovation Office. On the building industry branch of this project novel bridge girder technologies have been developed by the cooperation of the Civil Engineering Faculty of BME and the ZAEV Construction Co. These technologies aim to reduce the production time and cost, utilize the structural benefits of post-tensioning and ensure sufficient durability for products subjected to extreme chloride and freeze-thaw effects. The main outcome of the project is the full development of a brand-new, 0,9 m high bridge girder family made of self-compacting concrete. The use of self-compacting concrete is completely new in bridge girder technology in Hungary where high compressive strength both at young age and sufficient durability during 100 years of service life are the major demands to complete. For this purpose two mixes including lime filler and CEM III type cement as additions were designed and tested in laboratory and factory conditions. The practical applicability of internal bonded and unbonded as well as external unbonded types of post-tensioning with various layouts were tested on two-span prototype systems. Following the international trends to extend service life or to further improve the durability of bridges subjected to extreme environmental conditions can be either to use embedded fibre reinforced polymer bars instead of traditional steel ones as reinforcement in concrete or to structurally combine them with fully corrosion protected post-tensioning in hybrid-type bridge girders. The applicability of all these developments were demonstrated by failure load tests on full-scale prototype units of the girder family using an exclusive loading platform built on the storage area of the manufacturer. The developed bridge girder family already has CE marking.

Reaching new heights in the use of concrete prefabricated prefinished volumetric construction (PPVC) : Two blocks of 56-storey residential towers in Singapore

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Keywords: prefabricated prefinished volumetric construction, reinforced concrete composite structural wall system.

To reduce the reliance on foreign workforce and raise construction productivity, the Singapore building industry is encouraged to embrace the concept as per Design for Manufacturing and Assembly (DfMA) [1] whereby a substantial portion of construction works is done off-site in a controlled manufacturing environment. Prefabricated Prefinished Volumetric Construction (PPVC) modular system is one such technology that significantly reduces on-site manpower requirement and speed up construction. This paper outlines the pioneering & innovative PPVC technology of using a patented reinforced concrete composite structural wall system for construction of two 56-storey residential towers. Prototype sample tests such as compression test and shear tests had been carried out to verify the performance of this wall system; the test results show that this sandwiched combined wall system is able to perform under the actions of bending and shear in a composite manner satisfactorily. This development is currently the world's tallest residential building project constructed using the reinforced concrete modular construction technology.

Recent trends in floors production modified with waste materials

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Recently, in construction, for various reasons, the circular economy is starting to play a significant role. Various crisis situations in the form of a lack of available materials, an increase in the prices of materials have led to the fact that more and more scientists are looking for new creative replacement solutions. In the first place, these searches concern the materials that cost the most, and their modification is quite easy to carry out. An example of such an element are floors in which the underlay is made of a cement composite and the top layer is made of epoxy resin. In the case of industrial halls, the floors often constitute between 30 and 60% of the total cost of the construction. Numerous solutions leading to the modification of these materials are known. Recently it is common to use waste materials as substitutes which is in line with circular economy. Unfortunately, this knowledge is widely dispersed or its presentation is incomplete and often concerns only one of the materials. In this article, the authors plan to present the latest trends in comprehensive solutions for the modification of both materials.

Recycling of spent fluid catalytic cracking catalyst towards sustainable cementitious composites

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One of the approaches to reduce CO2 emission generating by cementitious industry is to use supplementary cementitious materials (SCM). Fluid catalytic cracking catalyst (FCC) is a material used in oil-refining processes, showing high chemical activity. Spent (FCC), which disposal is mainly limited to landfilling, providing considerable environmental risk and utilization costs, can be considered as a promising pozzolanic material using as a cement substitute. In present paper cement pastes with the use of spent FCC catalyst as a partial cement substitute within the range of 0-25%, were prepared and studied regarding both their fresh and hardened-state performances. Tests included pozzolanic activity of spent FCC as well as slump flow, compressive strength, flexural strength and absorptivity in the case of cement pastes. The results showed that spent FCC catalyst is an active material for pozzolanic reaction. Additionally, cement pastes prepared with its appropriate addition exhibited improvement regarding aforementioned properties in comparison with the plain cement ones. It is worth mentioned that such applicability of spent refinery catalyst might ensure numerous benefits both for construction and petrochemical sector, contributing to sustainable development.

The effects on cost, time, and accuracy when using unmanned aircraft systems to measure sloped excavations

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Keywords: efficiency, site work, survey, uas, construction

As uses for unmanned aircraft systems (UAS) continue to evolve, opportunities for research to validate improvements in cost, time, and quality become crucial. Specifically, there have been many studies focused on how UASs can simplify the measurement of earthwork quantities, but is there a compromise in the accuracy of the measurements for a reduced effort to obtain them? The objective of this research was to identify if such a compromise exists. This study measured the amount of effort (cost and time) to obtain a level of accuracy (quality) that is consistent with the traditional measurements obtained with ground-based robotic surveying equipment. The researchers performed a quantitative experiment using twelve measurement check points across a one-acre test site (4,047 m2). The test site was sloped to simulate a level of complexity that would be consistent with a more challenging area of a typical construction project site when obtaining earthwork quantities. The methodology involved measuring three separate UAS flights with differing flight paths and image gathering overlaps and comparing this to a ground-based measurement procedure. An accuracy analysis was conducted on the location of the twelve check points. Time and cost data were computed for all procedures and compared. This study found that not all flight path techniques met industry standards for accuracy while others did. The tradeoff when using the more accurate flight paths was a longer time to obtain and process data. When the overall cost was considered, it was determined that the UAS-based measurement approach was less expensive – resulting in a mixed determination about whether a "compromise" existed. This study further elaborates on the findings and proposes recommendations about how this comparison benefits innovation in the built environment.

Value engineering for performance improvement of sustainable construction project

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The technology of value engineering (VE) can be used to provide project owners with the required optimum value that is characterized by the project being delivered at the lowest cost and at a greater level of performance and quality level. Providing this value can be challenging or may be near impossible at certain instances that could eventually impair some basic and important principles of value management that are key in arriving at the goals of a project. This paper assessed the available conventional VE standard(s) with the aim of improving its ability to provide the best value to project owners especially in sustainability or green building projects. A critical review of the available standard VE tools and their uses in construction projects led to a discovery that project owners always emphasized reducing the cost of projects at the initial stages and sometimes during the whole life cycle of projects. This was identified as a limiting characteristic of the conventional VE that could hinder the project and VE team from performing VE exercises that meet the value requirements of projects. Performance worth (PW) VE approach was used to address this limitation in the function identification and analysis phase of the VE methodology. Construction industry VE practitioners were surveyed about the conventional VE and PW approaches, and their feedbacks used to test and/or validate the PW approach relative to sustainable project design and construction/engineering. The results of data analysis showed that PW was better than conventional VE approach and thus, it was concluded that its inclusion in the VE job plan would benefit project owners by providing better value or improved project outcomes. A new framework for VE methodology was provided to aid the VE team in providing the needed project value.

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A crack detection framework based on multi-data integration for structure maintenance

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The existing human-centered safety diagnosis method for structure maintenance has problems with time, cost, accuracy, and safety. Recently, many attempts have been made to quickly and accurately check the condition of structures for maintenance by utilizing equipment. In this research, a framework was established to derive the priority of repairing cracks based on a 3D model after data was obtained by combining LiDAR, high-resolution camera, and thermal imaging camera with drones. Drones serve as a moving object for obtaining data and can be used in places where it is difficult to access with manpower, thereby improving the safety of workers. The framework is as follows: Step 1 is obtaining data of a structure through each sensor, which is classified according to two purposes. In Step 1-1, Point Cloud Data is obtained through LiDAR, and crack images of the structure are obtained through high-resolutions camera. In this step, data can be obtained to determine the accurate location and size of cracks in the structure. In Step 1-2, thermal imaging data for measuring the depth of cracks is obtained through thermal imaging camera. Step 2 is processing and integrating data obtained through each sensor for 3D visualization of cracks on the structure. The PCD obtained through LiDAR is made into a mesh after removing noise, and a 3D model is constructed through texturing using high-resolution images and thermal images on the mesh, respectively. Step 3 is deriving the repair priority of cracks identified on the 3D model. Each crack has different characteristics such as location, size, and depth. For crack repair, cracks are classified according to grade and the repair priority is determined by considering the characteristics of crack. The framework can contribute to improving the economic efficiency, accuracy, and safety of structure maintenance by presenting criteria for deriving crack repair priorities.

A descriptive digital twin to support facility maintenance

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Keywords: Facility Maintenance, Digital Twin, Internet of Things, Power BI, Building Information Model

A digital twin is a complex dynamic digital representation of a physical space, asset or process. Digital twins are set up to include static (historic) data and to capture dynamic real-time data from connected sensors and other devices. Recent literature has shown that there is a need for more Digital Twin implementation research to explore ways to integrate available technologies, to define and test alternative digital twin system architectures.

This paper focuses on the development and implementation of a descriptive digital twin prototype to assist facility staff in monitoring performance of mechanical equipment for an academic building. The digital twin system architecture utilizes a Navisworks model for the mechanical room that was updated for missing graphical elements including missing pipes and valves. Graphical elements representing sensors were also added to the model. Static historical data collected from design drawings and submittals were loaded in the model and different tools including iConstruct Genus and BLogic VCAD were used to process the model file for import into MS Power BI. Real-time performance data collected from sensors attached to different equipment in the building mechanical room were linked to the model.

The digital twin implementation involved regular meetings with facility staff over a period of six months to understand how the performance data is read and interpreted for diagnostics and to receive feedback on the design and layout of the digital twin dashboards. During some of the meetings, some facility staff members self-navigated through the prototype to provide input on usability. Feedback received highlighted benefits realized from integrating static and dynamic data in a central platform that links the data to the graphical model. This provided for access to all types of information within a single platform allowing a faster response to address facility maintenance emergency requests.

A fundamental overview of the concept of quality in project management

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The importance of quality is now recognized in every expertise. Quality management has significantly evolved over more than the last half-century, and the methods and techniques involved have been developed, their levels described in detail. During this evolutionary process, quality has been defined in several quality management sources, and its interpretation has changed and been positioned at high levels. Although the role of quality in projects is critical, it has not been defined as well in general. Quality in projects has been addressed in numerous textbooks, international methodologies, and articles, yet it has not been harmonized.

This conference paper covers the first part of a research project with the ultimate goal of a proper definition of quality in project management, which will allow us to measure and predict quality during project execution. For this purpose, we review the definitions of quality and the significant milestones in general and project management. So, deriving from the research project, the goal of this paper is to overview quality in project management by comparing it with the scientific position in quality management. This research provides all the necessary bases to serve the objectives mentioned above. Through the final research findings, we could suggest future research that will bring project management up to date not only in the quality definition but also in the practice of quality management.

A pleliminary study on automatic interval measurement model for jack support

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This study proposes a model to measure the installation spacing of jack supports, which play a role in supporting the structure load during construction. The proposed model consists of two parts; one part is the jack support segmentation in an image, and another part is the installation interval measurement. The results of this study contribute to ensuring the construction quality of jack supports and further preventing building collapse accidents. For the further research, we will research the automated camera calibration algorithm to gain the angle and height of the camera.

A roadmap to a shared vision for platforms: The motivations and roles stakeholders in the transformation from projects to platforms

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Keywords: construction, platform, roadmap, stakeholders, ecosystem

In recent years, 'platform' has emerged as a buzzword for business. Despite widespread usage, there remains ambiguity in its meaning. Strategically, platforms capitalize on the advantages of commonality and have been successfully applied across multiple industries to deliver mass-customized products, increasing customer choice while maintaining efficient and effective production methods. It is known that the early involvement of stakeholders enables the platform logic, however that requires redefining their roles and motivations in the platform ecosystem. This paper aims to envisage redefined roles for each stakeholder in the construction value chain to create a shared vision roadmap by understanding their motivations for moving towards a platform ecosystem and how their engagement model will be changed. Five enterprises in Australia, that represent key stakeholders of the construction value chain, were selected for knowledge elicitation through individual discussions. The perspective pitches for the primary stakeholders comprise developers, general and specialized contractors, designers and engineers, while the rest of the value chain is grouped under associated stakeholders. In an attempt to define the new roles for the different stakeholders of the platform ecosystem, there emerged a shared vision that might enable a shift towards the platform approach. The intent for moving value-adding products and services upstream, expanding contribution to the value chain, continuous improvement through data-driven insights, seamless collaboration in a partnering environment and early prototyping were shared across stakeholder groups. A changed nature of engagement was observed where the general contractor ceased to be the single point of engagement with the associated supply chain actors; this role was most likely to be taken up by the developer or the platform consultant.

A statistic research on changes in the number of bidders for building works projects using the database in the Kanto region

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In order to ensure the transparency of public works, disclosures of competitive bidding results are widely practiced in accordance with Japanese law. The purpose of research is to collect bidding results data in chronological order and to observe fluctuations. The data collection range is the Kanto region including the Tokyo metropolitan area. We targeted bidding result information of building works over 100,000 data after 2000 fiscal year. First, we surveyed the characteristics such as type, region, scale of construction, and bidding method. Second, we analyzed trends in the number of bidders and successful bid rates, which were calculated by 5 owner organization category. Over the past 20 years, Japan's public procurement market has undergone a major system change from designated bidding to general competitive bidding. There are many construction markets where the number of participants per bid has decreased over time. Especially in Tokyo, not a little bids ended up with single bidder, which exposed the challenges of competition policy. In 2017 to 2018, the Tokyo Metropolitan Government had tried to cancel the project that was a single bidder, but finally gave up due to disturbance to the implementation of public works projects and the oppositions from the industry. In this paper, by analyzing bidding result data, we have described in detail the situation, such as when and in what layer the number of single bidding occurred. Other major findings are as follows: 1) Although the number of bidders tends to decrease at each owners, there are differences depending on the bidding conditions. 2) Looking at the long-term transition of the successful bid rate, it dropped around 2009 to 2011 after the Lehman Shock. 3) In many cases, it was also observed that as the number of bidders decreased, the successful bid rate increased.

An overview of breakdown of competences in managing major construction projects

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Project manager's competences have become recognized as one of key project management factors in successful delivery of projects in today's world. This paper gives a literature overview of existing competence models, with a special accent on competences breakdown, the main components and its relationship, obtained through systematic literature review. Moreover, authors give an application of theoretical knowledge on those competences that matter the most in construction industry, which is traditionally oriented towards technical elements of project management, but exposed to numerous people and context factors. This makes major construction projects great example of demonstrating project manager's personality importance in successful project execution.

Artificial intelligence in risk management system on infrastructure projects

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Infrastructure projects are crucial elements of the way we perceive the world we live in – they are pillars of economy and society development. In order for them to be carriers of change, they are ought to fulfil their goals successfully. With the rise of complexity of project endeavors, uncertainty to accomplish them successfully rises, too. Therefore, risk management, with the aim to identify, analyze, respond, monitor and control potential unfavorable events on projects, has an even more important role in complex environment such as infrastructure projects are. In order to contribute to todays' state-of-the-art risk management dealing with infrastructure projects, but also to identify the most crucial risks and the way project managers could deal with them, this research was conducted. Research sample consisted of EU co-financed infrastructure projects portfolio in water sector. First, risks were identified and analyzed by project managers. Then, the most critical risks and response strategies were identified for the whole portfolio. Systematic literature review was undertaken in order to identify possible strategies of dealing with identified risks. Afterwards, artificial intelligence was also engaged in order to formulate adequate risk response strategies. Both PM expert, literature-based and AI strategies were overlapped, and adequate conclusions were made, in order to contribute to more efficient implementation of risk management procedures on projects.

Balancing private investment and community expectations in privately financed infrastructure projects: A novel approach for evaluating long-term value

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Balancing private investment and community expectations is crucial in privately financed infrastructure projects, such as schools, housing, and hospitals. Evaluating the value of Private Finance Initiative (PFI) requires governments to accurately assess costs, risks, and benefits through their Public Sector Comparator (PSC). The Public Sector Comparator (PSC) focuses on the economic benefits and tangible value offered by bidders, such as whole-of-life financing costs, capital costs, operation, maintenance costs, and risk allocation as proposed by the government. Non-monetized benefits, which are important in social infrastructure delivery, are typically evaluated subjectively by comparing the specific solutions proposed by bidders. Assessing uncertainties in government requirements and materialized risks when comparing a bid to the Public Sector Comparator (PSC) using discounted cost techniques at a specific point in time is challenging. This paper proposes a new approach for evaluating investments that takes into account both monetary and non-monetary benefits over a project's life cycle, based on the risks and benefits seen in recent social PFI projects. Engineering reliability analysis is preferred to emphasize the performance reliability of investment decisions. The proposed reliability-based approach considers not only cost uncertainty and non-monetary benefits based on project observations, but also allows for time-based decision-making by being used at multiple points in time, to be incorporated into the original investment decision. An Australian school project was used to demonstrate that the proposed approach allows for predicting long-term value by using a performance reliability index to measure the robustness of the original investment assumptions such as demand projections and future sustainability outcomes.

Centralized operation of residential buildings: Case study from the past Budapest

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With the age of Big Data in the Facility Management, new centralized operational schemes are available. How those schemes meet with habitant requirements? The case study from the past, socialist Budapest provides a 40 years' experience for developers of new operation systems.

As a mega-organization, Budapest residential stock was operated by one centralized, state-owned company. The Author researched historical Budapest records of building operation from 1950 to 1990, gathering data about resources used for maintenance and renovation. In parallel, data was gathered about the client satisfaction, based on selected local daily publications. In Hungarian Socialism, residential segment and housing was a topic, where public has – limited - right to give criticism. This criticism appeared in various forms of publications, as reader's letters, jokes, journalist reports were published. The stock, applied resources and habitant's opinion were analyzed together in order to get the time trend of centralized operation.

The study may be used as a significant input for new, intelligent system of centralized Facility Management, however, as the political content changed, the possible usage of the study is limited.

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Challenges in adoption of public private partnerships for South African infrastructure development

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Public-private partnerships (PPPs) arrangements have proved to play a key role in the enhancement of the infrastructure development globally. South Africa's adaptation of PPPs strategies in infrastructure development, allows the government and private sector to work together in the delivery of much-needed public infrastructure services. This paper aims to summarise the views of professionals in South Africa's public-private partnerships (PPPs) platform on significant challenges facing the market for PPPs or policy framework in South Africa, concerning the challenges and how can we approach them. To achieve the aim of this paper, both primary and secondary data was sourced. The secondary data was sourced through an in-depth review of the literature. Quantitative method was used to source secondary data; the data collected using a structured questionnaire. The sample of 50 respondents was approached to partake in a study, respondents included built-environment professionals from both the public and private sector who are knowledgeable about PPPs. 34 of the 50 completed and returned questionnaires (a response rate of 68%). Following analysing the data received, the findings revealed that PPPs is a feasible option to enhance the delivery of infrastructure in South Africa; however, the government is reluctant to partner with private sector. Findings further revealed that the main factors hindering the growth of PPPs utilisation in South Africa is lack of PPPs awareness and insufficient research on the PPPs model. Besides, skills shortage, policy bias toward traditional public procurement, tuning of municipal PPPs legislation besides capacity constraints were also found to be a problem. This research calls out to the infrastructure development entities to pay particular attention to skills development in both public and private sectors, in order to have capacity and ability to adopt PPPs model in infrastructure development and have equal responsibility in ensuring that PPPs are advanced accordingly. Moreover, expedite constructive discussions on the challenges addressed and jointly develop robust solutions.

Computer vision-based tile counting model for automated progress monitoring

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Keywords: automated counting, computer vision, rectangular packing, tile work

Construction industry in Korea has grown based on apartments. Tiles are installed in most of bathrooms of apartment houses so the numbers of tiles are huge to manage. Therefore, this paper proposes a computer vision-based model for automated tile counting. This model uses line detection and rectangle packing algorithm. The results of proposed model appeared that the average of accuracy in line detection and intersection points extraction stage is 98.8% with standard deviation of 1.2%. In calculation stage, the proposed model shows 90.1% of accuracy with standard deviation of 9.4% This implies model can solve the overcounting problem by quickly and accurately calculating the number of tiles with images acquired by the inspector's mobile phone in the field. Furthermore, it can contribute to creating a transparent construction industry.

Concept for the application of business intelligence solutions for a semi-automated evaluation of construction process disturbances

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Construction time-related disruptions in construction projects usually lead to additional costs of approx. 30 - 50%. Furthermore, a disturbed construction process frequently creates conflicts between the contractual parties, while the high manual effort for creating and reviewing construction time claims is enormously time-consuming and error-prone. Accordingly, optimization potential can be identified to improve the efficiency of these processes. Overall, construction time claims are generally considered to be "excessive and non-transparent". Disturbed construction processes often result in a high degree of complexity and an associated high abstraction level within construction time claims, leading in many cases to a lack of transparency, traceability and comprehensibility of the situation or, under certain circumstances, even to a rejection of the construction time claims. Especially in terms of the progressing digitization of the construction industry, the application of digital methods to optimize the creation of transparent and verifiable construction time claims is an suitable approach. To address this circumstance, a concept for the partially automated evaluation of construction process disruptions using business intelligence solutions has been developed. The concept contains a structured database solution that analyzes the project-specific information and data in a structured and automated way according to the time- and cost-relevant effects of disruptions within the construction processes. Furthermore, in order to increase the transparency and comprehensibility of any disruptions to the construction process, a user-friendly dashboard was designed using a business intelligence application. Within that dashboard, the analyzed data is visualized and therefore comprehensible, transparent and interpretable concerning the individual disturbance circumstances as well as an overview of the entire construction project.

Construction 4.0 maturity tool with ontology development methodology for organisations

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In recent years the construction industry innovations have become an attractive market for investors. Innovations bring significant efficiency to construction companies while impacting business processes. Digital transformation in the construction industry is evolving slowly, as several criteria must be met simultaneously in order to be able to embrace these technologies for construction companies. In our research, we investigated which are the main pillars of the Construction 4.0 maturity model for organisations. As a result of our research, we created a Construction 4.0 organisational maturity model and verified the model by ontology development methodology. This model can help construction firms accelerate their digital transformation journey.

Development of a project objective system (POS) to align the interests of all the stakeholders and find the right delivery model

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Major projects often exceed estimated costs and deadlines. Therefore, they do not achieve the desired quality. The difference in objective interests of the project participants is a major problem. Based on the difficult contractual relationship and the late involvement of subcontractors, there is a lack of information for all those involved. This lack can be described by the principal agency theory from the economic field. The current project execution models do not have a smart objective system which records the interests of the client from start to the end of the project. They are not documented with the start of the project, neither adapted iteratively. With the help of the recently created project objective system (POS), the objectives of all project stakeholders can be selected, checked and compared. Later on in the project procedure the objectives will be transfer into risks. To know these risks and set the priority further on with the objectives. The probability for a successful project completion is much higher. Later, with the risk mitigation the objectives can be better safe. And the best fitting project delivery model can be chosen. However the risk profile of the project and the risk appetite of the owner, decide for the delivery model. As a result of the POS with the risk profile, for a very complex construction project the Integrated Project Delivery (IPD) with a cost-plus fee contract would be a fitting model. IPD with the contractual relationship, the early involvement of all the participants creates a sooner understanding of the project. This can reduce information losses and risks. With the POS the incentive contract can be created and thus an incentive mechanism developed. In addition, the project delivery on time and within the budget is strongly supported. The POS is a software app for better usability.

Development of evaluation criteria for the condition grade of steel pipe support based on regression analysis

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Keywords: evaluation criteria, quality management, regression analysis, steel pipe support

Steel pipe support is an essential, temporary material installed during construction to support the weight and construction load of concrete and formwork until the poured concrete gains sufficient strength. However, most steel pipe supports used in construction sites inevitably experience performance degradation owing to damage such as deformation, corrosion, and cracking. Therefore, reusing steel pipe supports necessitates strict quality management. In Korea, workers from temporary equipment rental companies classify the condition of steel pipe supports into three grades based on visual inspection: Grade A (reusable), Grade B (repairable), and Grade C (disposable). However, this criteria for assigning the condition grade is solely based on qualitative judgments, resulting in inconsistencies in the evaluation results. Therefore, the purpose of this study was to develop quantitative criteria for classifying the condition grade of steel pipe supports by performing regression analysis between the measured damage values and results of compression load tests on the steel pipe supports. Multiple reusable steel pipe supports were measured for damage and tested under a compression load, resulting in 150 datasets. From the collected datasets and regression analysis, threshold values for four items – support pin diameter, flange deformation, deflection distance, and screw thread depth – were derived. Based on these threshold values, a new evaluation criteria for classifying the condition grade of steel pipe supports was developed. The applicability of this evaluation criteria in the field is expected to ensure the reuse of steel pipe supports with good performance and reduce the number of related safety accidents in construction sites.

Effect of building information modeling (BIM) innovation on quantity surveying

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Quantity surveyors (QS) have various roles in the construction industry. One of their main roles is preparing bills of quantities that mainly entails taking measurements and pricing of construction work. They also develop schedule of project work, engage in construction project management, arbitration and dispute resolutions. Quantity take-off was their original role during 1820s when the profession was conceived. Critical observations brought criticisms alluding to the inability of the profession to survive if a tool could be developed that substituted QS roles in construction. Contingent to that criticism has seen the emergence of Building Information Modeling (BIM) that has specific attributes where the BIM technology can be used to quantify building works and produce schedule of works in 5D model interface. Thus far, has the BIM technological innovation posed threats to the QS roles and/or to the profession? The aim of this research was to investigate the effect of BIM innovation in the construction industry and to evaluate its effect on the quantity surveying profession. Is it a bane or boon to the QS profession? Specific objectives were to determine the extent of BIM usage by QS, the magnitude of relationship between the current BIM usage and the future of QS considering BIM growth in the construction field. Strength, Weakness, Opportunity and Threat (SWOT) analysis was conducted about BIM usage. Survey questionnaire was administered to investigate the effect of BIM, current usage and future standing in construction. The results showed that BIM was an opportunity that added to the progress of QS. It was concluded that QS needed to embrace BIM technology more with integration of digital twins for full benefit in the construction industry.

Engineering workforce planning and workload management in the US Army Corps of engineering

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Keywords: engineering, management, planning, workforce, workload.

Throughout the US Army Corps of Engineers, the process of workforce planning and workload management remains a challenge. The purpose of this research was to understand the tools available to assist with these functions, collect best management practices from leaders in the organization and engineering industry, analyze current processes and limitations, understand impacts of the current working environment on planning and management, and identify ways to improve mission delivery and more evenly distribute workload. The researcher used qualitative methods, including literature review and semi-structured interviews, to perform the research. Interviewees were from architect-engineering firms and USACE districts within the southeastern United States, all with experience working federal design projects. The interviews were followed by a demonstration of the tool developed by the researcher and team with additional feedback solicited to support further refinement. The responses provided during the interviews were analyzed to determine common themes – most critically, that there is no single tool identified that could perform both workforce and workload management functions and that all parties, whether part of USACE or private sector firms, were performing these tasks differently. Recommendations regarding best practices, implementation of the developed tool, and further training to ensure improved workforce planning and workload management along with opportunities for future research are provided.

Evaluation of modular construction methods versus traditional construction methods for army construction projects

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Keywords: construction, cost, facility, modular, traditional

This research study focuses on examining the Army's facility construction program during the fiscal years 2006 through 2013, known as Military Construction Transformation. For this program, the Army had goals to build better facilities, constructed faster and at less cost. To accomplish this, the Army gave contractors additional consideration for contract awards if the contractors proposed innovative design solutions, such as modular construction. This research examines construction costs, construction schedules, and maintenance records to determine if the Army's goals were met. There were more than 7,000 maintenance records available, covering more than ten years for the facilities evaluated. The results of the data revealed that modular construction is not providing the durability and maintainability that the Army paid for when compared to conventional construction through comparative case studies. A recommendation was provided as well as considerations for future research.

Evolutionary algorithms for construction site layout planning

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The arrangement of temporary facilities within the boundaries of a construction site is essential for successfully undertaking a project as it enhances productivity and ensures both safety and environmental protection. The Construction Site Layout Planning (CSLP) belongs among the most complex and challenging discrete combinatorial optimization problems involving multiple objectives and has been tackled using various methods from linear programming until heuristic and meta-heuristic techniques.

The magnitude and complexity of the problem grow exponentially as the number of necessary facilities and limitations increases. Thus, nowadays, metaheuristic techniques, mainly evolutionary algorithms, have patently been preferred for solving the CSLP problem due to their ability to provide efficient (near-optimal) solutions in acceptable computational time. Most of the existing studies focused on implementing a particular type among the evolutionary algorithms and evaluating its performance under specific, and mostly not clearly defined, conditions (case studies), making the comparative evaluation of the various algorithms practically infeasible.

This study aims to analyze and compare the efficiency of five different evolutionary algorithms in terms of solution quality and running time utilizing benchmark CSLP case studies retrieved from literature. All algorithms were developed on purpose for the present study using Matlab software. In an attempt to enhance the reliability of the results and effectively compare the algorithms, various sizes of the problem concerning the number of facilities involved were selected, aiming at minimizing the total traveling distances between all pairs of facilities.

Moreover, the performance of the algorithms was tested and evaluated in a multi-objective construction site layout planning problem. In this case, the aim of the optimization process was twofold associated with decreasing the travel costs related to the traveling distance and ensuring safety considerations in the construction site. Therefore, this research extensively reviews the efficiency of the tested algorithms in an integrated comparative framework for various size and complexity problems.

Experiences of countries with the adoption of the BIM-based permit process

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Construction projects are revolutionized by the introduction of Building Information Modeling (BIM) in the construction industry. It changed the way projects are managed and executed as a collaborative approach to building design, construction, and management. A relatively new concept that has been adopted in several countries around the world is the BIM-based permit process. This process involves the use of BIM technology to optimize the permit process for construction projects. The traditional process of obtaining a building permit involves multiple stakeholders and numerous steps and is often handled using paper documents or digital file submissions. Inefficient building permit procedures are considered time-consuming and prone to errors. Additionally, the demand for building permits has increased due to rapid urbanization, placing more significant pressure on regulatory authorities. This paper presents an analysis of the experiences of countries where the BIM-based permit process has been implemented: Singapore, Norway, Estonia, Finland and Netherland. Reviewing the existing literature and case studies, the advantages and challenges of this method are presented, together with the factors affecting adoption. The benefits identified include increased efficiency, improved accuracy, and reduced costs and delays in the permit process. However, there are many challenges, such as resistance to change and legal support. The paper also highlights the importance of government policies, stakeholder collaboration, and adequate training and education in successfully implementing the BIM-based permit process. The study concludes that the BIM-based permit process has the potential to improve the permit process for construction projects significantly, but its success depends on various factors.

Exploring essential change practices for the successful execution of organizational change efforts

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The past few years have brought major disruptions to historically stable industries. Events such as the COVID-19 pandemic, labor shortages, low-carbon initiatives, and infrastructure investments have been driving organizations to rethink their current-traditional ways and models of conducting business, and in turn, initiating major organizational change efforts. The capital projects industry is no exception, as capital project organizations are dealing with an endlessly changing environment that is continuously destabilizing the design, construction, delivery, operation, and management of capital projects. Thus, to remain successful in this changing environment, capital project organizations need to properly plan and successfully execute their change efforts. As such, the objective of this study is to investigate change practices that can be essential in supporting the successful execution of organizational change efforts and allowing organizations to effectively adapt to changing environments. To achieve the desired objective, a three-step methodology was adopted. First, a series of interviews were conducted with capital project organizations to learn about their past and ongoing organizational change efforts. Next, thematic analysis was employed to code common themes and identify the utilized change practices. The practices were then defined using the existing research corpus. The methodology resulted in a set of 60 change practices that are presented and defined in this paper. The findings of this study can be important for industry practitioners as they can use the change practices in planning and executing their change efforts, as well as researchers who can build on the change practices when investigating organizational change both inside and outside the capital projects industry.

Exploring the impact of technology on HVAC commissioning practices

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The primary method to ensure that systems are operating as designed is HVAC Commissioning, painstakingly stepping through a sophisticated process of running, testing, and verifying that the various components move, react, and respond in a way that fully utilizes the equipment and meets the environmental needs of the building occupants. The significant positive impact of technology on HVAC Commissioning is undisputed. Little research exists, however, on the field challenges and resource implications of rapid changes to HVAC components and control software for owners and contractors. This research explores solutions to the challenges that arise when advanced HVAC controls technology becomes burdensome and disadvantageous. The role of HVAC Commissioning within the very real constraints of federal mandates for energy use and the trend to convert from fossil fuels to "clean" fuels cannot be overlooked. The "trade-offs" encountered are substantial when highly sophisticated control sequences are utilized with HVAC equipment in the private sector and government facilities. The consequence of the lack of skilled technicians clearly has the opposite effect on utility savings. This research validates the effect of the practices of skilled professionals that make up the commissioning team to ensure that building HVAC systems perform as intended by the designer and building owner. Data was collected from commission professionals in construction, research and design fields. Qualitative data analysis yielded six primary themes that represent sub-themes that were repeatedly described as challenges, positive benefits or obstacles to progress. Thematic analysis of the primary themes peeked beneath the surface of the interview narratives to ask what is the structure that supports the major themes. Looking for broader implications and consequences, interpretation led to three proposed action topics. Recommendations are offered to improve commissioning practices by solving the implications of technology on human resources and developing partnerships with the industry that promote HVAC systems' efficiency. Finally, a compilation of industry experts' perspectives is laid out for re-aligning HVAC equipment, software, and controls technology to fully utilize the vast opportunities for utility savings, equipment longevity, and occupant comfort.

Exploring the role of industry 4.0 of the building industry: A case study innovative business model emergence on prefabrication in Australia

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The building industry is facing challenges in adopting advanced manufacturing techniques and technologies, and there is a need to communicate the inherent benefits of prefabrication, such as sustainability, to the broader industry. There is also a need to explore the interdependencies between the implementation of an industrial and digitally enabled building industry and business model and value chain innovation to shape digital platform ecosystem configuration. As prefab-manufacturing, building, and supply-chain industries play an essential role in industrial value creation, the article examines significant, yet understudied implications of Industry 4.0 along industrial value chains. This study aims to understand how the building industry in Australia can adapt to the shift towards industrialized-digitalization by exploring the opportunities for innovation in business models and value chains through the use of prefabrication. The focus is on understanding how to configure digital platforms and ecosystems to take advantage of the benefits of advanced manufacturing techniques and technologies, with a view towards shaping the future of the building industry in Australia. The research approach will draw on a literature review, the findings of previous projects and a series of workshops in four Australian cities utilising value canvas and business model canvas to capture perspectives determining value and delivering value. The examination of the implications of Industry 4.0 on small and medium-sized enterprises (SMEs) in the prefab manufacturing, building, and supply chain industries will illuminate how Industry 4.0 affects the three business model elements of value creation, value capture, and value offer for SMEs. The role of a company as a user or provider of Industry 4.0 and whether a company is internally motivated or externally pressured towards implementation have an impact on which business model elements are innovated. The research will help firms and managers to evaluate the promising innovations and their own position towards Building4.0. (maximum 300 words)

Impact of workforce training on worker performance and information access in the construction industry

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Keywords: workforce, training, performance, information access, craft

For decades, labor shortage has been a consistent recurring struggle in the construction industry. A well-trained craft workforce is crucial to maximizing the worker's potential and productivity. Studies in the existing literature have highlighted the importance of workforce training and its role in mitigating the impact of widespread workforce challenges and tight labor markets. Despite that, no research has yet quantified how training impacts workers' performance and the difficulty of the process to access information. The objective of this paper is to analyze and understand the impact of workforce training on 1) the self-evaluated performance record (including safety, attendance, quality, productivity, and initiative), and 2) the difficulty of the process to access information, of construction workers and frontline supervisors in the construction industry. To achieve the research objective, 2780 construction craft workers and frontline supervisors were surveyed using an online questionnaire. The survey participants were asked to self-evaluate 1) their work personal performance record, and 2) the difficulty of the process to receive or get access to information. The participants were additionally asked to specify how many hours of training they have completed in recent years including craft skills, job management skills, and planning skills. The collected data was then analyzed. Key findings indicate workforce training had a statistically significant impact in increased worker performance and information access.

Implementation of construction 4.0 technologies in the Turkish construction industry

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Keywords: Construction 4.0 technologies, expected benefits, problems in construction, questionnaire, Turkish construction professionals.

The construction industry is one of the world's precursors in labor force development and economic engagement. However, it confronts with several challenges. The digital revolution might provide some solutions to the encountered problems in the construction industry, which is traditionally slow to adopt the efficiency afforded by information technologies. There are numerous studies focused on the challenges faced by the construction industry. However, there need to be more studies investigating the level of construction professionals' recognition level of new technologies and their expectations regarding the problem-solving capabilities of Construction 4.0 technologies. This study aims to fill this gap by summarizing Construction 4.0 technologies, encountered problems in the construction industry, and the expected benefits from these technologies while comparing the perceptions of different groups of respondents' companies. Based on a comprehensive literature review, 13 Construction 4.0 technologies, 11 main problems encountered in construction projects, and 17 expected benefits from Construction 4.0 technologies were identified, and a questionnaire was developed. The questionnaire data obtained from 188 Turkish construction professionals were analyzed using a mean score analysis. According to the study's findings, medium/large size companies rated the recognition level of Construction 4.0 technologies and expected benefits of these technologies higher than micro/small firms, while they gave lower ratings for the main problems in construction projects. Additionally, construction firms working mainly on international projects gave higher ratings for Construction 4.0 technologies and main problems, while national and international enterprises had similar expectations for Construction 4.0's benefits. Likewise, enterprises with IT employees ranked Construction 4.0 technologies and the main problems in construction projects higher than those without IT staff, and the expected benefits of Construction 4.0 technologies were very similar. The findings of this study may guide construction professionals in deciding which innovations to support and encourage academics to create new technologies regarding real-world concerns.

Innovative tools for better use of the knowledge in facility management for construction

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Keywords: construction, facility management, knowledge, knowledge management.

Successful operation and maintenance of buildings relies on facility management (FM). Effective implementation of FM practices still poses diverse challenges. Through a comprehensive literature review, this research examines the current state of facility management and identifies the key gaps and challenges faced in this field. The findings indicate that major challenges concern inadequate information infrastructure, a lack of standardized processes, poorly identified required data, bad information quality and insufficient training. Common to the listed challenges is a need for a better management of knowledge. In this context, the paper explores the possible tools for better utilization of knowledge in management processes including centralized information sharing, continuous learning and improvement, and effective use of technology. This contribution demonstrates that the future research should focus on optimizing stakeholder engagement, streamlining processes and supporting knowledge, enhancing cognitive requirements, and the supporting technology to make better use of knowledge in the construction industry.

Multi-party contracts in the view of systems theory

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Due to rising demands, Construction Management as well as Real Estate Management are recently developing into increasingly complex organization issues. In particular, these fields are characterized by a very high degree of division of work and interdisciplinarity. Numerous participants are contributing their specific capabilities and skills as well as naturally pursue their individual goals. Traditionally, these contributors are interconnected via bilateral contracts, which are well-understood and theoretically modelled using the LEN-approach. Therewith, the unavoidable incompleteness of contracts is formulated and tackled via a fundamental estimation of incentives on both sides. More recent attempts to solving the challenges coming with the rising granularization of projects like Lean Construction and Agile Methods propose multi-party contracts instead, advertising the introduction of strong common goals to all participants. The paper presented here extends the LEN-model to multi-party approaches in order to estimate the required share of incentives to be distributed to the individual parties allowing for interconnected objectives and therewith common-targeted activities. This situation is investigated for different scenarios of forming the overall product, in particular for cumulative contributions as well as factorial contributions to the common objective. On this background, the fundamental, i.e. system-theoretical, limits of multi-party contracts are pointed out, discussed and thoroughly evaluated.

Small to medium sized enterprises in construction industry in Oman: opportunities, and challenges

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Government of the Sultanate of Oman has been creating 10 years of stimulating environment for small and medium enterprises in order to diversify the sources of income for the national product, one of the most important goals of the government is to reduce the proportion of its dependence on oil, which amounts to 80%, so the tendency was to create local companies dependent on other types of trade, therefore The Public Authority for Small and Medium Enterprises was established and the Al Rafd Fund, which funds these companies, and this process has remained for years, but there are still failures as the numbers of companies listed in the market decrease sharply and that most of the companies registered in the General Authority for Small and Medium Enterprises with unproductive activity On the contrary, a activity It will be imported from foreign markets, and this indicates the failure of the authority to direct the people who use the advantages provided by the government Tender to small and medium-sized enterprises, but the government still did not impose this on major companies and government companies that are the ones supervising government projects and whose duty is to award tenders for this category of institutions. Therefore, the main objective of this research will be to know the difficulties and challenges faced by these institutions and the reasons that make the owners of projects to avoid this category of companies.

Social acceptance assessment model for public construction projects using KoBERT

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The development of real-time communication technology has accelerated and enlarged conflict propagation, resulting in social conflicts in modern society. Social conflict significantly impacts the execution of a public construction project. Conflict of interest between stakeholders may cause construction delays and even cease the project. Against this backdrop, the authors aim to develop a proactive conflict management system based on Natural Language Processing (NLP) for public construction projects. As a point of departure, this paper introduces a social acceptance assessment model using Social Network Service (SNS) data. The authors employ Korean Bidirectional Encoder Representations from Transformers (KoBERT) for the text model development. The proposed model has two main functions. One is to filter out irrelevant text with the execution of a construction project. The other is to measure the degree of agreement on an ongoing construction project as social acceptability considering the semantic context of input text. Then, the social acceptability score is used to capture the inflection point that can become an indicator of significant social conflict in a public construction project. The proposed model is expected to detect potential social conflict signals through real-time monitoring, enabling the proactive reaction to prevent social conflicts during the execution of public construction projects.

The importance of feasibility study in the land selection process of projects: example of a residential land

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The construction industry requires large amounts of capital expenditure. There are many sub-units in the construction industry such as residential, commercial, road, bridge, etc. which is making the sector prone to many risks. One of the most important criteria at the beginning of the decision-making process in construction project is the selection of the right land. The cost analysis should be done correctly in the selection of the land and the benefit to be obtained from the project should be determined by considering all the details. Therefore, the feasibility study of the land can be compared with the investment cost and project benefit. In order to determine the suitability of the investment to be made, Net Present Value (NPV), Internal rate of return (IRR) and benefit/cost analysis criteria should be checked. This study covers a feasibility study for a project in Antalya. The study is aimed to calculate Net Present Value (NPV), Internal rate of return (IRR) and benefit/cost criteria. The purpose of this study is to emphasize the importance of feasibility study on land selection in projects. In the study, sample fields were selected for the purpose and feasibility studies were performed for these lands.

Theory of information in construction – implementation in critical infrastructures exposed to extreme events

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The Theory of Information in Construction based on the hypothesis that failures in critical infrastructures (C.I.) and are a result of loss of control in the information system of the CI as a result of information overflow of the system. The theory is established on four phases:

1. Statistical analyses:
    a. Probability density function of incoming events.
    b. The Cumulative Distribution Function (CDF).
    c. Power function expressing the magnitude of events.
    d. Scatter analysis.
2. Information Constraint (IC).
3. Control circuits.
4. Artificial Intelligence, Machine learning, Artificial Neural Network.

The hypothesis of the theory is that failures, deficiencies, accidents and cascading failures are the result of an overflow of information in the system beyond the system's capacity (IC). A similar hypothesis also refers to the performance of critical infrastructures, exposed to extreme abnormal events, resulting from climate change, terrorism and seismic events. The events put the critical infrastructures in an extreme situation causing high risk to the continuity of performance of the CI, society and citizens. This paper proposes a novel method for multi-hazard risk assessment of overhead transmission lines (OTL) grid. The main objective of this method is to estimate the annual risk using failure rates estimated from historical failure data and modify them by reanalysis data and a dynamic Bayesian scheme. For this purpose, a comprehensive database of structural failures is gathered. Digital Signal Processing (DSP), Proportional Integral Derivative (PID) and AI are implemented to predict the incoming events, assess the risk and propose preventive activities.

Workforce challenges and strategies of top contractors in the United States

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Keywords: construction, challenges, contractors, labor shortage

The construction industry is plagued with numerous workforce challenges. The skilled craft labor shortage has been a consistent and unfortunate recurring struggle for the past three decades. Moreover, recent trends show that the construction workforce has been aging rapidly, aggravating the labor shortage challenge and negatively impacting project performance in terms of cost, schedule, and safety. Studies in the existing literature have highlighted the different workforce challenges and strategies to address them and mitigate their impact, mostly from a research perspective. However, no research has yet studied how top contractors in the United States are dealing with these workforce issues. The purpose of this paper is to analyze the challenges the top contractors in America face and synthesize the strategies they employ to address these challenges and to recruit, train, and retain their workforce. To achieve the research objective, the authors analyzed recent annual reports of top contractors and summarized the challenges they face and the policies and strategies they have institutionalized to respond to current challenges.

CREATIVE SCHEDULING IN CONSTRUCTION

Next generation construction planning and scheduling: From reinforcement learning to transfer learning

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Keywords: artificial intelligence, deep learning, machine learning, project management.

In building and infrastructure projects, construction planning and scheduling refer to a process of defining project policies and procedures and breaking them down into specific construction actions. During this process, the "5W1H" (i.e., what to construct, when to construct, where to construct, who to construct, why to construct, and how to construct) becomes explicit under the constraints of six factors (i.e., scope, cost, time, risk, quality, and resources). Over the past several decades, construction planning and scheduling have been shifting from manual to automatic with the adoption of information and communication technologies, and building and infrastructure projects have benefited significantly from this change. In recent years, with the context of the booming development of artificial intelligence, there exists an opportunity for a new round of transformation and upgrading of the construction industry. To enable construction planning and scheduling to be autonomous, a framework for the next generation of construction planning and scheduling is proposed in this research. The proposed framework consists of two parts: (1) construction planning and scheduling relying on the self-project with reinforcement learning and (2) construction planning and scheduling relying on other projects with transfer learning. The elements of the two parts as well as their synergies are explored and discussed.

Activities of restricted duration in network time models of contruction projects

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Keywords: construction management, graph techniques, network techniques, scheduling.

Activities of fixed-, flexible-, intermittent-, distributable-, and unknown duration in general network time models are discussed in the paper on basis of preset lower and upper bounds on their time extent. After a short historical review, we discuss the theoretical background and we introduce a modified Floyd-Warshall algorithm to calculate networks of General Time Model (GTM) highlighting differences of well-known techniques of PERT, CPM, MPM and PDM. Finally, we publish a small construction problem to demonstrate practical application and modelling activities of these kinds.

An $\boldsymbol{\varepsilon}$-constraint method with adaptive mode elimination scheme for multi-objective mixed integer programming

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The significance of time-cost trade-off is well recognized for over five decades ever since the development of the critical path method. This trade-off originates from the fact that faster accomplishment of project activities, and thereby the project as a whole, is possible should there be more productive resources assigned. Increasing productivity, on the other hand, typically comes at a cost but possibly helps avoid incurrence of additional overhead and/or penalty expenses. The precise determination of the balance between the planned productivity and the aforesaid costs often poses a tough decision to make by the management. The process of finding the proper combination of execution modes gets particularly complex and computationally expensive for real-scale projects. Accordingly, to help set the proper balance between the time and cost of large projects, an ε-constraint method is presented in this study featuring a clever adaptive mode elimination scheme. The proposed approach involves the iterative optimal solution of the trade-off problem over the feasible project durations. For each project realization, the complexity of the optimization problem is first reduced with the aid of the adaptive mode elimination by discarding the redundant execution mode(s). This study uses mixed integer programming for formulation and development of the proposed model and uses a project example borrowed from the literature to experiment its usefulness.

Analysis of potential schedule-delaying elements for volumetric module transportation

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Modular construction is well known for its ability to provide numerous productivity and overall cost benefits over the conventional stick-built method through sophisticated off-site environments. However, although the advantages of modular construction are recognized, it is still considered a secondary means for delivering construction projects in the U.S. Consequently, modular projects often fail to achieve full benefits due to stakeholders' lack of expertise and experience. Existing studies examined the on- and off-site modular process optimization, whereas module transportation is relatively unconsidered. Among the modular benefits, the expedition of construction project schedules is paramount as it directly impacts the project delivery time. A meaningful portion of time for modular projects is allocated for transporting the completed module to its final installation location, and its optimization will contribute to the project schedule expedition. Accordingly, this paper, through the examination of the volumetric modular house transportation project, will identify potential schedule-delaying elements and recommend corrective measures that will minimize, if not eliminate them. Transportation time stamps were collected with the two sets of 2 channel dashcams installed inside the module and divided into three stages (Lifting, Transporting, and Offloading). The modular project took two days to complete, going over the anticipated 10-hour duration. The most impactful schedule-delaying elements were observed during the Lifting and Offloading stages due to the use of lumber stacks as temporary supports for hydraulic jacks and disconnected tandem axle dollies for the bogey support system. The analysis conducted by this paper will help industry stakeholders eliminate the schedule-delaying elements of modular transportation projects and achieve the full benefits of modular construction.

Automate and standardize multi-story building schedules through repetitive spatiotemporal model

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Keywords: Schedule, Automate, Multi-story buildings, Repetitive, Spatiotemporal.

Traditional planning models, based on Gantt-Precedence logic, focus on defining activities and establishing their constraints. Resources can then be assigned to those activities. Spatial constraints are usually neglected, resulting in site congestion or relaxation. This is due to the lack of representation of the sequence of work and supply flows on the site. Spatiotemporal models are considered more appropriate, especially for planning the construction of buildings projects. These models simultaneously consider activities, resources, and space as constraints to construct a realistic execution schedule. In addition, multi-story buildings share many common components and activities. Thus, it is plausible to think of establishing standardization in order to create an automated system to support the construction of validated schedules. The objective of this study is to develop an automated and standardized approach for creating construction schedules for multi-story buildings. Using the data from many studies, a mapping of multi-story construction schedules through repetitive spatiotemporal approaches can be created to allow for a consistent and systematic representation of the schedule.

Comparison of OEE-based manufacturing productivity metrics

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Overall Equipment Effectiveness (OEE) is a widely used productivity metric for different pieces of equipment. It provides information on the effectiveness of production, so the percentage of valuable operation time to planned uptime of the machine. The OEE, as the core metric of Total Productive Maintenance (TPM), helps to identify losses in production and quantify operational efficiency allowing actions to be taken that contribute to the continuous improvement of the plant. Despite or perhaps due to its popularity, OEE is not an accurate, well-defined measure. This is because the same considerations cannot be used equally well in different industries or may serve different purposes from one company to another, causing modifications in the calculation and measurement methods. Therefore, the OEE concept may mean other things from company to company, industry to industry. Researchers have tried identifying and overcoming the drawbacks of the original OEE by defining new calculations and creating new metrics. This study aims to overview the indicators available in the literature and compare their advantages/disadvantages. It also seeks to clarify these different definitions, naming conventions, calculation methods, and investigate their usability and the limitations of applicability.

Data acquisition system for automated updating of precast concrete project schedule

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In the construction project execution phase, the decision-making process greatly relies on the quality and timely data acquisition. The comparison analysis approach, i.e., as-planned vs as-built, is common for progress tracking in construction projects. This approach requires continuous real-time data acquisition from the construction site for further integration into a construction schedule for progress analysis. Due to the complex and dynamic environment on the construction site, the main goal of data gathering efficiency increase lies in its automation. This paper presents a data acquisition system for automated updating of the precast concrete project schedule. The system is BIM-based, in which data collected from the construction site, i.e., actual starts and actual finishes of assembled elements, are automatically transferred and integrated into the project schedule. In the BIM environment, each element is uniquely determined by its work breakdown structure (WBS) code, which corresponds to its quick response (QR) code in the project schedule attached to the element on the construction site. The first discrete scan of the code on the construction site marks the actual assembly start of an element, and upon its assembly, the last discrete scan marks its actual finish. The system automatically transfers the data into the project schedule and updates the following assembly activities. The system was applied to a precast concrete project case study in laboratory conditions. The system performed smooth and efficient data collection, transfer, and integration into the BIM environment.

Discussion on the range of interpretation of EVM-type project management indicators

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Tracking and monitoring become particularly important during the implementation phase of projects; however, participants should maintain some form of tracking and monitoring at all stages. It has taken decades for the use of milestones to be accompanied by sophisticated methods, even those required by law. Earned Value Management (EVM) is a managerial method used to control projects in terms of cost, time, and progress. Although many researchers have studied the EVM concept, only a few have attempted to suggest EVM frameworks for concurrent analysis of additional elements beyond time, cost, and progress. The importance of EVM is indicated by the fact that it is now a permanent chapter in methodologies and standards. The Project Management Book of Knowledge (®Guide, 2017) describes EVM as an approach that incorporates schedule, cost, and scope to assess and measure the project performance. ISO 21508:2018 specifies Earned Value Management principles for project and program management. It applies to any kind of organization, public or private, in any size or sector, as well as any project or program, regardless of complexity, size, or duration. In the meantime, several studies have shown EVM's shortcomings, and several researchers have proposed possible solutions (e.g., Earned Schedule or Earned Duration). This conference paper will summarize the most critical and recent additions, and the authors will suggest further extension possibilities and their motivation. The proposals are based on some analysis.

GIS-based schedule and cost performance tracking for oil and gas construction projects in sultanate of Oman

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Construction industry in the field of oil and gas is one of the most important major industries on which the Omani economy depends, as it is one of the most important areas on which it has relied within the Sultanate of Oman in terms of economic and development over the past 50 years, and it is always common in oil and gas projects in the Sultanate of Oman exceeds The project has the specified time period (schedule) as well as the specified cost. The objectives of this research are to study the factors and causes of delay in the schedule and cost Overrun in oil and gas projects in the Sultanate of Oman by assessing the root causes of exceeding the cost of construction projects, assessing the most important factors affecting performance and productivity in projects, as well as analyzing the effects and cost overruns and the schedule prepared for projects in the oil and gas field In Sultanate of Oman, there are several reasons that lead to these problems including ,additional work by the owner, poor planning before and during the project, a lack of resources for contractors and fluctuation of prices for building materials, lack of experience with the contractor or lack of skilled labor, to achieve The objective of this research I will use quantitative approach through the distribution of a questionnaire to staff and managers in the field of oil and gas whether contractors or project owners Also an interview with the project manager at the Petrofac Oman. The expected results of this research are determining the reasons that lead to schedule and Cost Overrun by evaluate the root causes of exceeding the cost of projects and find appropriate solutions to reduce them, to achieve maximum benefit from these projects and achieve sustainability in the Omani economy.

Productivity improvement and developing framework for roads maintenance: a case study of Johannesburg roads agency and eThekwini metropolitan municipality

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Keywords: capacity improvement, roads maintenance framework, roads maintenance standards, productivity improvement.

Municipalities in South Africa (SA) are battling to maintain their roads infrastructure utilising internal maintenance teams. The greatest concern among municipal staff seems to be a perceived lack of long-term performance and maintenance data (R. Lukes & C. Kloss, 2008). Several municipalities are struggling to operate and maintain their infrastructure in a cost-effective manner (IMESA, 2012). These municipalities are not providing enough maintenance budget for operations and maintenance which leads to poor infrastructure maintenance and resulting into ever ending infrastructure backlogs. There is a long turnaround time in attending to service requests in these municipalities and this might lead to potential accidents when repair work takes longer. There is also lack of efficiency and effectiveness to improving productivity by municipal maintenance internal teams

The developed framework standards for operation and maintenance of roads infrastructure for municipal teams will reduce turnaround time in attending to service requests, improve productivity and assist government allocation of resources per maintenance work activity. This will lead to systematic way of attending to maintenance work ensuring over 80% utilization of resources (plant, labour and material) and reduced wastage and idling time.

Scheduling repetitive construction processes using a swarm algorithm

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This article presents a method for multi-criteria optimization of repetitive construction processes schedules. Considering the limitations in planning the realization of such projects using classical tools and methods, the use of swarm algorithm for finding non-dominated solutions to the problem was proposed. An example of the application of the particle swarm optimization algorithm to the development of a schedule for the repetitive construction processes realization and the selection of work crews in order to minimize the realization time of the project and downtime in the work crews was also presented.

CREATIVE SCHEDULING IN CONSTRUCTION

Study on simulation technology to evaluate working time from BIM data and mesh data

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Research on four-dimensional (4D) building information modeling (BIM) simulations has recently been actively conducted. However, the 4D BIM simulation often draws the installation order of the building parts. Therefore, only a few studies have analyzed the changes in working time owing to differences in the installation order of building parts. In this study, the effect of the difference in the installation order of the building parts on work time was investigated. After reproducing the construction site in the virtual space, an agent that shuttles between the stockyard and the installation location was created. This agent can move around and avoid newly installed members as construction progresses. Therefore, the total moving distance of the agent changes depending on the installation order of the building parts. Based on changes in the total moving distance, a method was devised for evaluating the goodness or badness of the installation order of building parts. Subsequently, the developed simulation system was applied to install studs on the partition walls. In addition, the simulation system was applied to new constructions and renovation works. When applying the system to renovation work, simulations were performed using mesh data created based on the point-cloud data of existing buildings.

The behaviour of influence lines of schedule networks with maximal relationships

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Keyword: CPM, Precedence Diagramming Method (PDM), Influence lines

The internal rules of influence lines which show the transitions of activities' criticality types, were previously investigated in case of PDM networks, where the four minimal end-point relationships or point-to-point relations were allowed. This paper examines the effects of the introduction of maximal relationships on the criticality types and their behaviour. The research contributes to a better understanding of influence lines, and the effects of changing an activity's duration on the project duration.

THE criticism of the evm method

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The Earned Value Method (EVM) is the most widely used method of controlling project time and costs, with roots dating back centuries, but it was only formalised and standardised in the 1960s. This article summarises the most significant criticisms of EVM, which are: a) the calculation of incorrect data for the existing situation, b) the production of incorrect forecasts for the future. The errors can be of such magnitude that they can completely misinform project stakeholders about the status of the project. The magnitude of errors generated by EVM is illustrated by sample examples.

The reasons are manifold and are discussed in detail in the paper. © 2023 The Authors. Published by Diamond Congress Ltd.

SUSTAINABLE CONSTRUCTION, HEALTH AND SAFETY

An overview of predictive models of chloride penetration in concrete

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Keywords: chlorides, diffusion, models, sorption, transport mechanisms.

Corrosion of reinforcement has a major impact on structural performances and service life. This is especially pronounced in reinforced concrete structures exposed to the marine environment, whose degradation is accelerated by chloride penetration. Therefore, the process of chloride penetration is one of the most important parameters when designing reinforced concrete structures, predicting their service life, and planning remedial measures and maintenance. Engineering calculation models can be divided into empirical and physical models, based on different physical expressions depending on the dominant transport mechanism or their interdependent combination. Different numerical and analytical methods are used to solve them. Also, we distinguish deterministic and probabilistic approaches to modeling. The first model of predicting chloride penetration in concrete was presented by Collepardi in 1970. Since then, the model has been significantly improved and developed into sophisticated models, most of which take Fick's laws of diffusion as a starting point. Today's models often encounter limitations and unreliability in use and long-term predictions due to the lack of understanding of the combination of transport mechanisms under real exposure conditions, the time dependence of the apparent diffusion coefficient, quality long-term data and the determination of boundary conditions. This paper presents an overview of models aimed to predict the penetration of chlorides in concrete, with an emphasis on transport mechanisms by diffusion and sorption, or their combination.

SUSTAINABLE CONSTRUCTION, HEALTH AND SAFETY

Assessing the overheating risk in residential buildings: A case study in Palestine

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Keywords: climate change, overheating risk, Palestine, residential buildings, thermal comfort.

Palestine has faced numerous challenges and severe hazards in recent years, including overheating events caused by climate change. These events have led to discomfort among building occupants, health issues, and increased energy consumption. Many residential buildings worldwide, especially in the warmer summer months, are at a significant risk of overheating. However, research on the impact of heatwaves on existing residential buildings in Palestine is limited, highlighting the need to investigate building performance in extreme climates. This study aims to address this gap and has three objectives. Firstly, identify the current situation regarding the effects of overheating, its causes, and its potential consequences. Secondly, to analyze the overheating risk of existing residential buildings and assess the thermal comfort of vulnerable occupants using a semi-quantitative approach and a matrix method to rate the risk. Thirdly, to evaluate the overheating risk using well-known standards such as ASHRAE 55, CIBSE TM 52, and TM 59. Climate change is taken into account by using future weather data projections based on different scenarios. Simulation results show an increasing risk of overheating in the future, which will disproportionately impact the most vulnerable populations. Therefore, efforts must be made to mitigate this risk. Passive cooling strategies may be insufficient to reduce overheating hours during intense heatwaves, so a combination of passive and active cooling strategies should be considered. In conclusion, this study highlights the importance of considering the impacts of climate change on building design and performance. It underscores the need to evaluate the overheating risk of existing buildings and develop strategies to mitigate it, which can ensure a safe and comfortable indoor environment and promote climate-resilient buildings.

SUSTAINABLE CONSTRUCTION, HEALTH AND SAFETY

Auxiliary equipment for working at heights: Workers' perception of safety issues

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Falls from height are a relevant occupational health and safety problem, given the great impact they have on an injured worker, as well as on their families and the company to which they belong. Although most countries are trying to reduce the number of accidents due to this cause, the injuries resulting from these accidents are usually serious, and in a significant number of cases they are fatal. In addition, it should be considered that high-rise construction in large cities continues to increase due to the scarcity of land, so the risk of accidents in this type of construction will be a constant in the future that must be adequately addressed.

The causes of falls from height are varied, including lack of control by the direct supervisor, irresponsibility of the worker or wrong handling. Also, they can be caused by auxiliary elements (platforms, ladders, machinery or others) required for the execution of a task, which are poorly assembled or unsafe.

This article provides the context of the use of auxiliary equipment (fixed and mobile scaffolding, and safety rail) for work at height. Then, a field information survey is carried out to describe the main problems regarding their use on site. Finally, through the application of 44 semi-structured interviews to construction professionals and supplier companies in the Chilean market, different appraisals on the safety of working at heights and the use of auxiliary equipment are described.

The results show that the relevant aspects in the use of auxiliary elements to prevent the risk of falls are related to the singularity of the projects under construction, the scarcity of regulations or their updates, in addition to the lack of technical information on site that would allow the constant verification of auxiliary equipment, among others.

Barriers to sustainability practices in the Turkish construction industry

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With the increase in the world population and technological developments, human needs have undergone a rapid change and the consumption rate has reached the highest level. High consumption rate causes energy resources to fall to critical levels, posing a great threat to the future. According to the 2022 Global Status Report for Buildings and Construction data, the construction sector has been determined as the sector that causes the highest energy use in the world with a rate of 34% and CO_2 emissions with a rate of 37%. This situation has increased the interest in sustainability in construction projects and many academic studies have been conducted on this subject. However, in developing countries such as Turkey, sustainability practices in the construction sector have not reached a sufficient level. In this study, it is aimed to identify and prioritize the obstacles to sustainability practices in the Turkish construction sector. Literature review and Expert opinion were consulted in determining the obstacles on sustainability practices in the Turkish construction sector; Fuzzy AHP technique was used to prioritize obstacles. It is thought that the results of the study can form a basis for the development of sustainability practices in the Turkish construction sector and the development of strategies for removing barriers.

BIM-based seismic risk assessment framework for infrastructure systems

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Keywords: Building information modeling (BIM), Seismic risk assessment, Infrastructure, Fragility curves, Vulnerability.

Building information modeling (BIM) methodology has been widely adopted for engineering projects, such as buildings, bridges, pipelines, and roads. However, BIM has yet to be fully utilized for risk assessment of critical facilities with multiple infrastructure systems. In this study, a BIM-based seismic risk assessment framework is proposed. The digital BIM model contains component-level information on the building's structural and non-structural elements, and this digital data allows the execution of component-based analysis of seismic risk. The seismic vulnerability of the components can be evaluated according to fragility curves, where each model element is attributed its corresponding fragility parameters. Each model element is assigned the median and standard deviation capacity for each damage state. Subsequently, various seismic scenarios can be simulated. The results of the simulations allow quick assessment of the seismic performance of the infrastructure and identifying the most vulnerable components. The proposed framework provides a valuable tool for engineers and decision-makers in assessing the seismic risk of infrastructures and implementing necessary measures to increase their resilience. Our preliminary work shows that BIM can provide valuable information and visualization tools for seismic risk assessment and can help improve the efficiency of the assessment process.

Construction equipment emission control status, policies, and regulations in China

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Diesel-power construction equipment emits pollutants that pose a serious threat to the environment and health of construction workers. To address the environmental challenges of the construction equipment, the governments have imposed stricter emission requirements for construction equipment than ever before. This paper conducts a review of China's current emission status of construction equipment, emission standards for diesel equipment engines and equipment operations, a summary of China's related emission regulation policies is made, and a comparison analysis is conducted with some developed regions such as the United States and EU countries.

SUSTAINABLE CONSTRUCTION, HEALTH AND SAFETY

Design and natural materials – innovative approaches for a sustainable future architecture and structural engineering

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Keywords: metal sheet lightweight structures, mycelium composites, off-knot design, parametrical tools, raw wood design.

Perceptible limitations of resources, energy and agglomerations of waste cause modern societies to consider and expand research on sustainable and natural principles. In this context, the building construction sector, with its large impact on material consumption and landfilling, requires special attention and consideration. Strategies may include: using recyclable materials, reducing material waste and entropy, and using bio-based materials that can be returned to the natural material cycle without any treatment or separation processes.

The paper gives an insight into the design and elaboration of lightweight metal sheet structures, approaches to the use of raw wood for structures and structural purposes, and the material design of mycelium composite components for construction purposes. Parametric design tools enable the control of complex geometries both at the general and detailed level of metal sheet shells and folded plate structures. New approaches like Off-Knot-Design combined with digital taxonomy and parametric tools provide a new way to design frame, truss, or beam-like structures from raw wood parts. Material design principles and the use of symbiotic biological properties help develop fungus and wood composites that can be disposed without further post-processing. The shown approaches demonstrate how well-known materials such as metal sheets and old materials such as wood lead to innovative sustainable solutions through interdisciplinary knowledge combined with modern algorithms and tools.

Diseases in construction workers: a critical review and research opportunities

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Keywords: chronic noncommunicable diseases, construction workers, health.

Currently, there is a need for change in the construction industry to respond to an increasing competitive pressure for more productive systems. Thus, given the concern for improving productivity levels in the industry, it is necessary to face the problem from all perspectives.

One of these perspectives of analysis is the worker, who plays a key role in the productivity and final results of a project. This is especially relevant in those parts of the world where construction work remains labor intensive, so occupational and chronical diseases become of interest. Healthier workers are physically and mentally more energetic and robust, more productive and less likely to be absent from work due to illness. Although many employers are now concerned about the health of their workers, their efforts have focused more on medical costs (insurance) than on interventions to understand the impact of health on workforce productivity.

Through a systematic review of literature, this article describes the status of some occupational and chronical non-communicable diseases in developing countries and how they affect productivity in the construction industry. This will make it possible to have clarity on the diseases that affect construction workers and that have been most studied, such as cardiovascular diseases, chronic respiratory diseases or diabetes, and also to identify diseases whose impact has been little studied and that require further analysis in order to propose concrete actions to deal with them.

Thus, cardiovascular diseases, chronic respiratory diseases and diabetes are the most analyzed diseases in the construction sector. But mental health, musculoskeletal disorders and audiological diseases are also becoming relevant.

Empirical study on cost risk in international construction project

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Keywords: international construction, cost risk, risk evaluation data

Since the multidimensional uncertainties, the international construction market is a more risker market rather than domestic construction market. Sustainable business in the international market requires accurate project diagnosis and proactive response strategies through the risk assessment process and it is necessary to provide empirical risk evaluation data to support more accurate risk assessment in aspects of practice. This study, therefore, aims to analyze and provide risk evaluation data which contains key risk factors, risk impact and probability in aspects of cost performance. The 124 international construction projects conducted from Korean contractors were used in this study. The key risk factors were derived by comparing low-performance project and high-performance project in aspects of cost performance and the results are suggested by product types which are civil structure, building and plant. The study found that 'Insufficient period for construction completion', 'Weather and climate uncertainty' and 'IT based project management difficulties' are the high ranked risk factors regardless of product types. It also found that contract risk had the greatest impact on business in international market since lots of high ranked risk factors are belong to contract risk. The results of this study can be used as a reference data for practitioners to evaluate the risks of international construction projects and will support them successfully carry out the project through more accurate risk assessment based on past case data.

SUSTAINABLE CONSTRUCTION, HEALTH AND SAFETY

End-to-End pavement defect classification and localization using deep learning

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Automated detection of road performance data has historically been challenging for the pavement management industry. As a result, new methods have been developed over the past few years to handle this issue. Most of them relied on supervised learning techniques, such as object detection and segmentation methods, which need a large, annotated image dataset to train their models. However, annotating pavement defects is difficult and time-consuming due to their ununiformed and complex shapes. To address this challenge, we propose an end-to-end pavement defect classification and localization framework using deep learning. This framework has two steps: (1) a robust hierarchical two-level weakly-supervised classifier to classify the defects in images, and (2) a supervised segmentation module to localize the defects in images without needing to annotate defect locations. The feature maps extracted from a weakly supervised method (i.e. Class Activation Method) results of the first classifiers are used to train a segmentation network (i.e. Unet or MaskRCNN) to localize and segment the defects in the images. Thus, our proposed framework combines the advantages of semi-supervised and supervised methods simultaneously. Additionally, the proposed method benefits from an asset management inspection system based on Geographic Information System (GIS) technology to prepare the dataset used in the training and testing.

A dataset from a Georgia State in the USA was used in the case study where roads are subject to climatic hazards, having a significant impact on the conditions of the roads. The proposed framework obtained high precision of 99%, 96%, 100% and 99% for localizing the alligator, block, longitudinal and transverse cracks, respectively.

Evaluation of wood fly ash as a cement replacement material in concrete

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Keywords: biomass; wood fly ash; supplementary cementitious materials.

Biomass is the largest source of renewable energy in the European Union, of which 60% comes directly or indirectly from forests. The most common way of producing energy from biomass is combustion, and this process yields a substantial quantity of ash. The cement and concrete industry have been identified as one of the main potentials for biomass ash utilization. This paper presents the results of an experimental study aimed at determining the influence of wood fly ash on the properties of concrete. Wood ash was sampled from three power plants using different technologies of incineration and different types and parts of wood were used as a fuel which consequently had a large impact on the properties of ash. Subsequently, workability, heat of hydration, stiffness development, 28-day compressive strength, apparent porosity, and capillary absorption were determined on concrete mixes prepared with WFA as cement replacement from 5–45% by weight. Cement replacement up to 15% with the finest WFA accelerated hydration, stiffness development, and increased compressive strength of concrete up to 18%, while replacement with coarser WFA's led to a decrease in compressive strength of up to 5% and had more gradual heat liberation. The dominant effect that could explain these findings is attributed to the filler and filling effect mechanisms.

SUSTAINABLE CONSTRUCTION, HEALTH AND SAFETY

Green building: An antidote to sick building syndrome menace in Africa

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Sick building syndrome (SBS) is the leading cause of the reduction in the building's occupancy level of satisfaction, poor indoor air quality, and other shenanigans responsible for the underperformance of building occupants and loss in property value. Thus, this study proposed adopting green building (GB) as an antidote for reducing the causes of SBS. The challenges impeding the adoption of GB as an antidote for SBS were also examined in this study. The methodology adopted in this study was broken down into three-phase, with the first phase focused on the data collection. The study adopted a random sampling in collecting data (questionnaire) from construction stakeholders within the study area. A total of one hundred and twenty (120) questionnaires were collected from the respondents within the study area. The questionnaire was analysed using SPSS V 24, adopting frequency distribution, mean score, principal component analysis, and multiple regression analysis. The causes of SBS are divided into the ambience and individual-related factors. The findings from the multiple regression analysis revealed that green building (GB) has a higher chance of functioning as an antidote for eliminating the ambiance-related factors. Unfortunately, factors such as insufficient technical knowledge of green building components, green building occupants' behaviour, and maintenance/construction cost hinder the adoption of GB as an antidote for SBS. This study contributed to creating innovative ways towards eliminating SBS in Africa. The article presented a two-way directional framework that reveals the solution and challenges for adopting green building (GB) as an antidote for sick building syndrome (SBS). Numerous articles have identified the causes of SBS, but there is a shortage in the literature regarding a suitable solution or antidote for eliminating the specific cause of SBS.

Integrated concrete mix design with sustainability, cost and durability based on artificial intelligence

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Concrete production accounts for a substantial portion of global CO_2 emission. One of possible ways to reduce the carbon footprint of concrete is to optimize the concrete mix design approach. This paper investigates the integration of sustainability, cost and durability performance with concrete mix based on artificial neural network. Carbonation-induced corrosion resistance is used for characterizing the durability performance of concrete mix. A dataset on natural carbonation coefficient, compressive strength and concrete mix design of concretes with various supplementary cementitious materials (SCMs) is established. An artificial neural network is trained, and used in designing a concrete mix with optimized sustainability, cost and durability performances given a target compressive strength. The results show that the artificial intelligence is promising in integrated concrete mix design with favorable sustainability, cost and durability performances.

Implications of the market shift toward renewable energy on a construction organization: A case study

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In 2015, the United Nations established a set of 17 Sustainable Development Goals to initiate a global roadmap that targets an essential transformation of energy access and transition by 2030 and achieves net zero emission by 2050. The roadmap was further accelerated after 2019 when the COVID-19 pandemic placed a stronger focus on sustainable development. With the great emphasis placed on environmental regulations and the increased investments supporting low-carbon initiatives, construction organizations recognized the importance of their industry and started acting by shifting to the renewable energy market. This market shift, however, has major implications for construction organizations. Thus, it becomes crucial to understand how the market shift toward renewable energy is affecting the organizational aspects of construction companies including strategy, structure, people and culture, and processes and technology. This study presents a case study on a large service provider company (Company X) that has been going through a market shift and organizational change since 2019. Network analysis was performed on transcriptions from four semi-structured interviews conducted with company representatives to understand: (1) the drivers of this market shift toward renewable energy (weight of the past, push of the present, and pull of the future); (2) the response of Company X to successfully implement this organizational change (implications on strategy, structure, people and culture, and processes and technology); and (3) the challenges that the market shift toward renewable energy imposed on the organization. The findings of this paper offer a preview of the dynamics of the market shift toward renewable energy organizational change and enable informed dialogue around the drivers of, response to, and challenges of the market shift toward renewable energy in the construction industry. Organizations undergoing or planning a market shift toward renewable energy change can reflect on the idnetified practices to successfully navigate through this organizational change.

Negative carbon concrete for achieving next generation of sustainable and durable modular integrated construction (MiC): A Review

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Sustainable construction is currently in much demand as construction industry produces a huge amount of CO2, exacerbating global warming. Modular integrated construction (MiC) is set to become a prominent solution to achieving the "carbon neutrality" initiative in Hong Kong, offering high productive efficiency. The concept of "low carbon construction" is proposed by the use of low carbon construction materials and the optimization of project management. However, there remains great potential in the use of these methods in reducing carbon footprint during the design and construction process. This paper firstly reviews possible pathways to reducing the embodied carbon of reinforced concrete. A novel concept known as "negative carbon concrete", which is potentially achieved by combining CO2 mineralization – the natural carbonation of concrete with other low-carbon construction materials – is proposed. The durability performance of fiber reinforced polymer (FRP) bar-reinforced concrete can be improved by concrete carbonation. The application of negative carbon concrete in MiC is discussed from material-level to urban-level. Analysis indicates that negative carbon concrete may be used to achieve next-generation sustainable and durable MiC.

Potential of structural multi-objective optimization of reinforced concrete slabs in the context of sustainable development

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Keywords: parametric modelling, structural multi-objective optimization, reinforced concrete slabs

Reducing material usage and ensuring adequate performance and safety of bearing structures became fundamental aspects of modern engineering design and optimization. Reinforced concrete slabs in multi-storey buildings transfer vertical floor loads and horizontal shear loads to other bearing elements, such as walls, columns, or beams. They provide stability and contribute to overall structural integrity. Especially in large structures with a repeating floor plan over several storeys, material consumption in reinforced concrete slabs can add up quickly. Structural optimization aimed at reducing material usage can provide significant benefits in terms of sustainability and conservation of resources. This paper presents a recommendation for a framework of structural multi-objective optimization (MOO) of storey slabs made of reinforced concrete and highlights the need for efficient use of resources, especially in the context of sustainable development. A case study of the suggested structural MOO-framework is carried out on an existing concrete slab of a large residential building using "C-SLOP" (Concrete SLab OPtimizer), a tool developed for this purpose. Using the case study results as a basis, input parameters for the optimization process were calibrated in order to obtain more realistic results, to consider the structural aspects from the execution phase and to find an optimized design solution. The paper highlights the importance of multi-objective structural optimization of simple common bearing parts, such as reinforced concrete slabs, in early stages of structural design and emphasizes the potential for material savings in the construction industry.

SUSTAINABLE CONSTRUCTION, HEALTH AND SAFETY

Risk analysis of underground tunneled SMR NPP against munitions' hits

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Civil society is increasingly exposed to terror and war threats. The scenario caused by these threats are highly relevant to the continuous performance and safety of Critical Infrastructures (CIs). CIs might be exposed to guided munition hits with high penetration capabilities. Maintaining the continuous performance of CIs is crucial in ordinary times and even more so during emergencies. A passive protective solution is robust and reliable compared to alternative solutions and may be superior over time. Underground structures protect sensitive facilities such as military infrastructures and recently also Nuclear Power Plants (NPPs) from highly explosive charges. The research objective focused on developing a risk-informed optimal decision support methodology for advanced CIs resilience, particularly underground NPPs, exposed to earth-penetrating weapons (EPW) hits. Threat scenario of GBU-28 guided bomb unit (GBU) defined the test case of penetration and detonation above an underground cavern that contains the NuScale Small Modular Reactor (SMR) reactor building. The research methodology was composed of the following phases: literature review; underground critical energy infrastructures vulnerability assessment, focused on SMR; hydro-dynamic numerical simulations of selected threat scenario of underground SMR hit by high explosive warhead, also called munition; analytical-empirical formulation of the in-structure shock; damage assessment of the SMR critical components and its containment structure exposed to munitions' hits; development of fragility curves due to blast waves based on NPP components' tolerance under airplane crash, and seismic fragility curves. The research findings reveal that the severe threat scenario of a GBU-28 hit on the caverned NuScale SMR yield significant Large Radioactive Release (LR) probability of the order of $3 \cdot 10^{-4}$ for peak accelearatipn of 5.2g. This scenario must be further developed for risk mitigation alternatives.

Study on the relationship between sustainable cities and urban engineering management in undeveloped countries - A case study of Timor-Leste

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Keywords: sustainability, project management, urban engineering

Sustainability is the most important issue to be aware of in the modern urban engineering construction. The goal of a country's urban sustainability is in the process of urban construction combining the concept of urban engineering and construction management which in order to achieve the residents safe and comfortable living life. In the developed process of an undeveloped country, it often emphatically focus on economic development, which leads to the destruction of environment and ecology, further resulting in a tremendous irreversible damage to the city. Timor-Leste recently has actively carried out national construction projects, including all kinds of public buildings, roads, airport, hospital, factories. Hence, all neighboring countries engineering experts and investors are attracted to embark on this trend.

This study will review past engineering management issues and experiences of urban development as well as literature on sustainable cities, and conduct expert interviews in East Timor to explore the interdependence between urban engineering management and sustainable cities, and provide strategic guidelines for the engineering construction process of urban development in undeveloped countries. To lead the urban development and project construction process towards the goal of sustainable, peaceful and happy life.

Viability of off-grid containerized reverse osmosis water treatment in Maiduguri, Nigeria

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This research serves to explore options to provide clean water to communities impacted by water shortages in Maiduguri, Nigeria. This research is meant to provide possible solutions to a water crisis that has mainly been addressed through emergency management. This work explores the viability of solar-powered reverse osmosis water treatment over local boreholes/shallow wells. To explore solutions, several related fields were investigated, to include methods of water purification, the application of these methods to borehole water that is pumped to the surface, the viability of solar power as a power option, and the assessment of the water needs and challenges in the described region.

The research conducted was mixed method, with both qualitative and quantitative data collection. Technical interviews with water treatment manufacturers and needs assessment interviews with WASH professionals provide qualitative data. NGO-provided multi-sector needs assessment data and water quality results from Maiduguri boreholes allows for development of water treatment methods and provide quantitative data.

Needs assessment data and interviews with WASH professionals demonstrated that there is a need for decentralized water treatment with off-grid capability due to energy and water security gaps within the city. Water quality results showed that the level of Total Dissolved Solids (TDS) in untreated water does not necessitate desalinization-style water treatment. Technical interviews with water treatment manufacturers suggested that reverse osmosis is too power intensive and requires more water rejection than ozonation, which is a small-scale water treatment technology that has shown itself to be viable in Nigeria. These results will allow the integration of off-grid water treatment into the medium- and long-term municipal water security planning for Maiduguri. Reverse osmosis remains a viable water treatment process, but ozonation will allow for less power- and water-intensive water treatment, therefore ozonation is the more sustainable option.

SUSTAINABLE CONSTRUCTION, HEALTH AND SAFETY

VISUALIZATION, VIRTUAL REALITY BIM AND 3D PRINTING FOR DESIGN AND CONSTRUCTION

A case study of BIM projects in hospital construction – comparing Germany to the international status

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The effective communication and coordination between all participants are a prerequisite for efficient project management. Especially in complex constructions, a high degree of coordination and communication is required due to an increased potential for errors in the project execution. Hospitals, as buildings of critical infrastructure, represent very complex constructions with increased regulations. Furthermore, there is an additional trade of medical technology, and an increased number of stakeholders need to be coordinated. The method Building Information Modeling (BIM) offers an efficient opportunity for transparent communication and provides a database of the building over its entire life cycle. In addition, there are many other use cases using BIM to benefit the management of the hospital, such as model-based quantity and cost determination or the use of a digital twin for facility management. BIM is becoming more established worldwide and also in the field of hospital construction BIM is already used. However, the scope of BIM application varies significantly among different projects, highlighting the need for a more detailed examination of existing or completed hospital projects.

This report compares various international hospital projects regarding the application of BIM whereas 10 out of 20 projects are in Germany. The information required for this case study is obtained by literature research. This provides an overview of the present state of BIM implementation in a global comparison, which provides the basis for the development of specific standards for the use of BIM in hospital projects. This enables the advancement of the implementation of BIM in hospital construction and the exploitation of the highest possible benefits over the entire life cycle to operate hospitals in a future-proof, sustainable and economical manner.

A descriptive digital twin to support facility maintenance

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Keywords: Facility Maintenance, Digital Twin, Internet of Things, Power BI, Building Information Model

A digital twin is a complex dynamic digital representation of a physical space, asset or process. Digital twins are set up to include static (historic) data and to capture dynamic real-time data from connected sensors and other devices. Recent literature has shown that there is a need for more Digital Twin implementation research to explore ways to integrate available technologies, to define and test alternative digital twin system architectures.

This paper focuses on the development and implementation of a descriptive digital twin prototype to assist facility staff in monitoring performance of mechanical equipment for an academic building. The digital twin system architecture utilizes a Navisworks model for the mechanical room that was updated for missing graphical elements including missing pipes and valves. Graphical elements representing sensors were also added to the model. Static historical data collected from design drawings and submittals were loaded in the model and different tools including iConstruct Genus and BLogic VCAD were used to process the model file for import into MS Power BI. Real-time performance data collected from sensors attached to different equipment in the building mechanical room were linked to the model.

The digital twin implementation involved regular meetings with facility staff over a period of six months to understand how the performance data is read and interpreted for diagnostics and to receive feedback on the design and layout of the digital twin dashboards. During some of the meetings, some facility staff members self-navigated through the prototype to provide input on usability. Feedback received highlighted benefits realized from integrating static and dynamic data in a central platform that links the data to the graphical model. This provided for access to all types of information within a single platform allowing a faster response to address facility maintenance emergency requests.

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Collaborative virtual reality in construction comparative study of two remote multi-user systems

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Keywords: Remote multi-user virtual reality, BIM, remote collaboration, Unity game engine, Vizard, Photon Unity Networking

Ineffective collaboration and communication between the stakeholders of a construction project are one of the most difficult problems to solve in the AEC industry. In recent years, the rapid development of new technologies has reformed the construction industry. Indeed, adopting BIM technology and its dimensions improves the collaboration process. The integration of emerging technologies such as virtual reality (VR) based on a BIM model is a potential solution to optimize communication. However, most of the studies on virtual reality and its applications in the construction industry have so far focused on the single-user experience which does not support collaboration and interaction between construction project teams. Multi-user remote virtual reality can offer a solution to the problems mentioned above. Several tools have been developed in other fields such as the video game industry, but their applicability in the construction industry has not been evaluated in the literature. Our research aims to compare two remote multi-user virtual reality support systems to characterize their potential use in the construction industry with BIM models. We then performed a demonstration in the form of two fictitious scenarios to evaluate the proposed tools. This allowed us to identify the potential benefits of the two remote multi-user VR systems to support collaboration and to identify limitations and future improvements. While both systems offer interesting remote multi-user functionality, the Vizard multi-user application can only work over a local area network, which is a major limitation to remote user collaboration. In addition to the features common to both systems, Photon (PUN) offers the ability to communicate with voice in real-time.

Interdisciplinary approach in achieving optimised lightweight load-bearing slabs

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The paper presents the possibilities of interdisciplinary design methods in architectural optimisation design using concrete load-bearing slabs. In the process of multi-criteria architectural-structural optimisation, the benefits of using free-forms, in which weight minimisation is the overriding parameter, are increasingly recognised. The research addresses this topic by proposing the topology optimisation methodology of lightweight structures following the bending moment diagram and the internal force flow of load-bearing elements in response to the current needs of sustainable architecture. The search for material minimisation and managing the construction processes in the AEC sector is supported by interdisciplinary collaboration from architecture, construction, materials engineering, biology and fabrication. This paper investigates strategies for receiving optimal weight and possible digital fabrication methods using contemporary additive manufacturing possibilities. However, topology optimisation and manufacturing managing process of free-form structures remain a challenge, and this study aims to help implement those strategies at the early stage of architectural design. A comparison of results on FEM and BESO optimisation methods on simple load-bearing structural elements is presented to validate the approach to further research in the field.

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New horizons for a worker-effective training method in the AEC sector

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Keywords: Building Information Modeling, Construction Site Information Modeling, Digital Simulation, Gamification, Training.

The training of site professionals is typically perceived as being monotonous, and ineffective in terms of information assimilation and retention. Furthermore, traditional training approaches such as lecture-based presentations, have been demonstrated to be unsuccessful at engaging site workers, resulting in decreased attention and motivation. This paper aims to develop the framework for gamified training, specific to infrastructure site workers. It is intended to value the requirements that European H&S standards expect to be kept under surveillance. The outcome of this work is the definition of a new reward procedure focused on ongoing improvement via feedback to low-scoring individuals. Multiple screen boards are designed to facilitate key context interaction and possible reactions. This study outlines two theoretical applications of training, the first applicable transversally to many situations (*i.e.* Educational Construction Site Information Modeling) and the second as a site-specific solution based on its digital twin (*i.e.* Mockup Construction Site Information Modeling) intended to accurately foresee and train workers for dangerous operations.

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Production of biomimetic structures using Voronoi tessellation and 3D printing technology: Possibilities and practical issues

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This paper discusses the development of a new algorithm for determining the internal tissue density of structural members using the finite element method and Voronoi tessellation. The study aimed to reduce the density of structural elements while maintaining their original purpose by filling the interior of the members with interconnected strut members to replicate the structure of animal bones. The strut members were created using the edges of Voronoi cells, and stress was used as an additional variable during the Voronoi iteration to prevent stress concentration on the strut members. The proposed approach resulted in a more uniform stress distribution in the strut member than when Lloyd's algorithm was used. However, perfect uniformity was not achieved due to certain factors, and several issues were identified during the 3D printing process. These findings will refine the proposed algorithm to achieve perfect uniformity of stress distribution in the following steps. The approach presented in this study offers unprecedented opportunities for modern engineering to create structural members that are equally resistant to internal stresses as observed in animal bones.

Removing indoor clutter objects in the point cloud for the generation of as-built BIM Models

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Keywords: Point cloud, Indoor clutter, As-Built BIM, Two-Dimensional Projection, DBSCAN

Removing indoor clutter objects is one of the critical challenges during the point cloud processing. These indoor clutter objects decrease the modeling accuracy of As-built BIM models. Several related studies have proposed valuable methods to remove indoor clutter objects in point cloud data using RANSAC and Clustering. However, these methods have limitations, such as easily ignoring minor indoor structural elements and frequently misidentifying elements with similar geometric features. In this study, we propose a novel method to effectively remove indoor clutter objects in the point cloud. Our approach starts with a 2D projection of the point cloud to emphasize the point density differences between indoor clutter objects and structural elements. Also, we combined various algorithms such as voxel-grid downsampling, density-based spatial clustering of applications with noise (DBSCAN), statistical outlier removal (SOR) filters, and radius neighbors regressor algorithms to achieve our goal. We evaluated our proposed method using six actual scan datasets and demonstrate that it achieves a mean accuracy of 0.94, mean precision of 0.97, mean recall of 0.90, and mean f1-score of 0.93. Our method outperforms commercial point cloud processing software in classifying and removing indoor clutter objects in complex indoor scenes acquired from construction sites. Despite some indoor clutter objects having similar geometric features with structural elements, our proposed method successfully classifies the indoor clutter objects in point cloud data. Our proposed method has the potential to significantly improve the accuracy and precision of as-built BIMs by effectively removing indoor clutter objects.

Research on workflow improvement in the early stage of apartment design using BIM

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The purpose of this research is to show the concrete and effective design study process by generating the effect of BIM utilization for both the client and the architect in apartment design. The unique strategy is considering the use of BIM based on its structural characteristics. Generally speaking, one distinct feature of BIM is said to lie in "3D (shapes) + information". BIM is also said to change up conventional workflows. However, is this unique "shape + information" approach enough to completely transform workflows? Is it possible that we still have not been able to explain BIM in a theoretical manner? In order to answer these questions, I have looked at BIM in terms of its structural characteristics, and have verified the effect of use methods derived from such structural characteristics using simple case studies. My research focused on the various grouping features provided with BIM. With BIM, it is possible to accurately reproduce reality as "group" of nested objects, such as a factory unit in which a precast concrete wall and a sash are integrated. In a digital space, it is also possible to create "group" of nested objects of "volume", while not showing up as actual composite elements. In this research, we devised "dwelling unit volume group" and showed that it facilitates the study. In addition, I created "group" of structural members that are the "skeleton" of the apartment, "group" of standard types of dwelling units that are the "infill" and created the object library. Furthermore, using BIM visual programming, I devised a method for automatically arranging and adjusting the "group", quickly creating BIM model of apartment and creating easy-to-check documents. I was able to show the effectiveness of the "group" library, of utilizing in design, visualization, environmental simulation, cost control and workflow improvement.

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The role of project supervisor within the BIM execution plan

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Keywords: CoSIM, Construction Site, BEP, Health and Safety, Project Supervisor

In the AECO sector, the BIM approach is used for the management and exchange of information between the different stakeholders involved in the development of a project. Central models, available on CDE, store the information that could be retrieved according to the role and to the specialism involved. Drawing the right set of properties is crucial for successful workflows, hence cross-information is fundamental to achieve information exchange between disciplines, managed by each BIM coordinator. According to ISO 19650 series the client specifies those requirements in the EIR, nevertheless few cases show the implementation of Health and Safety measures in it. European Directive 89/391/EEC on health and safety (H&S) on workplaces and more specifically the directive 92/57/EEC addressing Project Supervisors can be both seen as a beacon in this field for their clear and neat list of compulsory and optional requirements. This work aims to create an integrated standard example to be used from the clients at the tender stage (pre-BEP) to verify and validate the completeness of H&S design outcome. Such integrations aim to facilitate the information flow among the different specialists reducing the occurrence of onsite accidents.

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The theatre metaphor for spatial computing in architectural design

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Keywords: computational design tools, early architectural design, sketching, spatial computing, theatre metaphor.

Decisions made in early design phases are particularly important for the entire architectural design process. The most formative of early design techniques is sketching. Sketching directly in 3D space offers significant advantages for form finding, making shape and structure immediately apparent through heightened spatial awareness. Such a computational early design paradigm also enables real-time data exchange, facilitating the communication process between different AEC professionals. However, new digital technologies require new conceptual approaches to help potential users understand existing and envision new use cases and applications. Moving from desktop computing to spatial computing (virtual, augmented, mixed and extended reality environments) also requires the introduction of new metaphors. New interaction and visualisation possibilities afforded by current devices are causing virtual and real worlds to merge into an inseparable unity of reality and imagination.

There are many similarities between theatre and AEC workflows. However, the theatre process is scaled down in terms of space, time, and budget, and is therefore better suited to explore innovative and experimental methods. In order to conceptualise the role of a novel spatial computing drawing tool (MR.Sketch) in existing AEC processes, we propose the theatre metaphor, which embeds the conceptual foundations of the tool in a collaborative design workflow based on the cooperation of different domain experts.

The metaphor proposal includes the analysis of the following theatre concepts: integrative collaboration with specialists, stage infrastructure, workshops for different tools and manufacturing methods, stocks and the immersive experience of space and time in different scales. We illustrate the capabilities of the theatre metaphor to cover the entire creation and performance process of architectural design in an experimental mixed reality sketching application. The implementation of an early prototype of the sketching application was used to evaluate the applicability of the theatre metaphor to spatial computing.

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Urban energy recycling: An architectural road map

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There is a strong link between energy recycling and urbanism. Cities are major energy consumers, and as the world's population continues to urbanise, the demand for energy in cities will only increase. At the same time, cities also generate significant waste and unused energy. Energy recycling can help address both of these issues by capturing and converting this waste and new energy into valuable energy that can be used to power homes, businesses, and other infrastructure within the city. Energy recycling has the potential to play a critical role in the development of sustainable and energy-efficient cities. Urban areas can become more self-sufficient, resilient, and environmentally friendly by capturing and converting waste and unused energy into valuable energy. The paper aims to analyse energy recycling procedures in cities. The research analyses the possibilities of reducing waste, greenhouse gas emissions, energy security and increased energy efficiency. The result of the paper assesses a road map for urban energy recycling in an Architectural and Urban context.

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