Guest editorial: Working smarter by applying advanced technologies in construction: enhancing capacity and capability in construction sector for infrastructure project delivery

The transformational mindset is gradually prevailing amongst the construction industry professionals. Various research have been conducted on the application of new technologies, digitisation, information systems and advanced decision-making methodologies (Babaeian Jelodar *et al.*, 2022). Building information modelling (BIM), visualisation tools, sensors, blockchain and automation to construction activities are some examples of recent advanced technology applications in construction research (Eliwa *et al.*, 2022). Artificial intelligence has also been applied to integrate and apply different concepts and advanced tools within the construction settings (Darko *et al.*, 2020). There is also ample evidence of the application of expert systems, management information systems and other advanced technologies that has paved the way to facilitate the move towards digital strategies in construction (Sutrisna and Goulding, 2019; Sutrisna and Kumaraswamy, 2015). Different apps, software platforms and Internet of Things (IoT) tools are being used in combination with BIM-based approaches to enhance smart systems in construction (Belsky *et al.*, 2016; Li *et al.*, 2017; Lu *et al.*, 2017). In addition, the terminology of Industry 4.0 has also been recently expanded to construction sector and is gaining popularity (Oesterreich and Teuteberg, 2016). The construction sector is clearly interested in moving towards smart, digital and antonymous systems; minimising human intervention to improve productivity and accuracy and eliminating potential sources of error (Babaeian Jelodar and Shu, 2021).

In spite of the technological advancements, however, the construction sector is still segregated and lacks a systematic approach to mitigate the problems stemming from low productivity and technology uptake (Gupta *et al.*, 2018; Pan and Zhang, 2020). In spite of decades of efforts, productivity enhancements have been considered negligible within the construction sector (Savolainen *et al.*, 2018). There are also severe imbalances in demand and supply within the construction industry. The main question posed here is how advanced technologies and smart systems can not only enhance the creation of more capacity but also sustain and expand capability in the construction sector. The sector is extremely vulnerable to disruptions, resource fluctuations and external crises. Its vulnerability is particularly exposed in times of difficulty such as financial crisis and the recent global pandemic of COVID-19, which has affected the delivery of crucial infrastructure projects. Advanced technology applications can assist with different activities and hold the potentials to restore some of the impacted productivity. The annual global infrastructure spending is between US$6 and US$9tn, close to US$78tn in a period of ten years from 2015 to 2025 (PWC, 2017). However, according to the world economic forum, there is a current significant spending gap of over US$5tn which is expected to rise to US$15tn by 2040 (Oxford Economics, 2017). Whilst there is a clear need for increased spending, embracing innovation, working smarter

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and collaboratively to enhance capability and capacity will also have a significant impact in bridging this gap and saving global economies valuable resources (Chen *et al.*, 2018; World Economic Forum, 2019). Therefore, the topic of developing smart systems and technological advancements in facilitating, building and sustaining capacity and capability is of significance for infrastructure development and a necessity for the construction sector.

This special issue focuses on the adoption of these smart systems and technological advancement to facilitate the delivery of infrastructure projects in a more effective manner. This allows for novel, more proactive, real-time and effective actions within the whole project lifecycle to enhance productivity, save costs, free more capacity and create new capabilities, rather than perpetuating reactive approaches to the sector problems.

A total of seven articles are included in the special issue. The articles cover a range of construction and built environment related issues and phases. This involves technologies used in construction site and phases. The first article by RazaviAlavi and AbouRizk reports the development of a simple-to-use simulation tool for site layout and construction operation planning purposes in the context of tunnelling projects. The intention of this study was to advance application of simulation in tackling construction site layouts issues. An integrated environment for modelling tunnel construction operations, site layout and their mutual impact was created via a simulation-based decision support tool. A special purpose simulation (SPS) tool was developed and customised for mechanised tunnelling projects using tunnel boring machines. The tool was specifically designed to also cater for users with limited amount of simulation knowledge. The SPS tool provided great assistance for analysing different site layout and construction plans. The study promoted simulation application in construction research and practice, specially for more informed decision-making for sites layout and planning.

The second article by Amiri Ara *et al.* focused on blockchain as an emerging technology to improve supply chain efficiency of engineering, procurement and construction (EPC) companies, specifically in oil and gas infrastructure development. The case study approach was deployed, an EPC company as well as its supply chain had been selected and analysed. Information flows were mapped, and supply chain inefficiencies were identified based a review of literature. Following steps include identifying the root causes of the inefficiencies, and a comparative analysis were conducted between the application of linear and the blockchain information system. A specific design for blockchain systems was identified and completed; accordingly, a cost–benefit analysis was carried out. The designed blockchain system was proven to be a viable solution in reducing inefficiencies.

In another research on blockchain, the third article by Akinradewo *et al.* investigated the barriers to the implementation of this emerging technology in South Africa. A survey questionnaire was conducted and principal component analysis (PCA) was used to analyse the results. The most significant barriers were identified as lack of clarity, scalability risks and lack of skills or knowledge. Furthermore, based on the performed PCA, the three main themes of organisational barriers, social barriers and technological barriers were identified. The outcomes of this study provide a solid platform towards realistic solutions to blockchain implementation. This will likely enable the construction and built environment sector to enhance capability and capacity in line with other sectors.

The fourth article by Vithanage *et al.* focused on off-site manufacturing (OSM) as a modern method of construction and the safety risks associated to these methods. A systematic literature review was conducted to identify OSM safety-focused publications in key construction research electronic databases. Accordingly, bibliometric and content analysis was used, and a taxonomy of risks associated to OSM was developed. Within the context of OSM, safety aspects were identified; then accordingly risks were identified and classified under human, organisational and work environmental factors. Seven research classifications of OSM were identified via content analysis of the selected literature. Furthermore, recommendations were made to enhance OSM safety. Recommendations included targeted safety management concepts, technology-driven safety measures and bespoke training programs. If correctly implemented, these recommendations hold the potentials to reduce uncertainties and streamline processes associated with these methods and hence, will contribute to increase productivity and enhanced capabilities within the construction sector.

Article five focused on prototyping IoT-based systems. Zhou *et al.* used a cyber-physical system to develop an architectural prototype which can improve occupant's health and well-being outcomes. The prototype goals, attributes, data sources and potential were identified. A system architecture was designed with embedded software and hardware required foe IoT connections. The prototype was validated by a case study, and based on this, a monitoring platform to collect share, store and analyse indoor environment data was created. Whilst the study focuses on health and well-being implications; such IoT technologies can be used in other pre- and post-occupancy phases of a construction and built environment project. The monitoring platform developed in this research will enable accurate and timely data collection of built environment facilities. This will facilitate future design and inspire changes to the construction, facilities management and maintenance of buildings.

In article six, Elghaish *et al.* applied deep learning techniques and convolutional neural network (CNN) models to detect and classify highway cracks. Three categories of "vertical cracks", "horizontal and vertical cracks" and "diagonal cracks" were subsequently identified, sampled and used for model development. Four pre-trained CNN models were tested and their corresponding accuracies were evaluated. Accordingly, a novel deep CNN learning model was developed to maximise crack detection accuracy. Three different optimisation algorithms of stochastic gradient descent with momentum, Rmsprop, and Adams where applied. Whilst the best pre-trained model had an accuracy of 89.08%, the developed deep learning CNN model achieved accuracy of 97.62%. This demonstrates the detection power of such tools and models, which can significantly enhance maintenance of the vertical infrastructure. In addition, these tools contribute to the automation processes adding more capacity to the construction sector at an enhanced capability level with minimal error.

Finally, in article seven, Danquah *et al.* looked into the awareness of design requirements to enable future technology applications. The focus was on formwork design in Ghanaia construction industry; which significantly contributes to the construction phase and is often a critical activity. Lack of awareness and traditional practices have led to formwork accidents and major cost and time overruns in construction. Expert interviews were used to valuate awareness of industry professionals on formwork design concepts. The findings indicated minimal awareness of the concept, design regulations or any code of practice, and the professionals believed a code of practice and further training will be required. The article also emphasises the use of technology and specifically BIM technologies for design and training of such activities which are often classed as temporary works. This can also significantly enhance productivity, wait time and resource occupancy, which can also lead to enhanced organisational and sector capacity.

The collection of articles included in this special issue demonstrates the applications of advanced technologies to different activities and phases involved in construction and delivery of infrastructure projects. These articles champion and enable more proactive, in real-time actions while taking into account the whole project lifecycle to enhance productive, facilitate economic gains, free more capacity and create new capabilities to known construction problems. It is the guest editors' anticipation that through the articulation of current *de facto* practices of advanced technologies and smart systems, it will lead to dissemination of valuable, applied and hands-on knowledge for the construction sector. The line-up of authors from different parts of the world also brings in different perspectives and industry expertise in dealing with different policy and regulation setting. This will enrich the current body of knowledge to potentially assist key industry participants and stakeholders in decision- and policy-making.

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