Editorial: Special Issue on Developments in Construction 4.0

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Built environment has been perennially caught up in low productivity conundrum for a long time. This is despite its significant impact on industrial employment (i.e. over 6.6% contribution) and representation of 9.8% of the UK's Gross Domestic Product (Rhodes, 2019). Poor collaborative processes through effective information exchanges has been identified as a major reason for this (Crotty, 2013; Kumar, 2015). Besides, the knowledge gap between design and construction has also been cited as a major contributor to this discontinuity (Abrishami *et al.*, 2014; Fruchter *et al.*, 2016; Goulding and Pour Rahimian, 2019; Goulding *et al.*, 2015; Pour Rahimian *et al.*, 2019; Pour Rahimian *et al.*, 2008; Pour Rahimian *et al.*, 2011).

Over the years, leading experts from industry and academia (Egan, 1998; Latham, 1994) have contributed to the dissection of the drivers behind this and suggest solutions to address these issues. However, it has taken major developments in digital technologies like the internet, project extranets, building information modelling (BIM), IoT among others to generate the kind of optimism that the industry has never experienced before. Built environment is not alone in sharing the excitement around these technologies. These technologies have captured the imagination of just about every industrial sector. Of course, no technology can result in addressing the challenges of any industry on its own. A set of complimentary processes (Goulding *et al.*, 2015; Kumar, 2015) need to be developed in tandem for the technologies to be effective enablers of change. Quite encouragingly, such processes have been developed recently particularly in relation to information management and collaborative working in the built environment sector. These are positive developments and whose veracity and effectiveness will be tested over the next few years.

Meanwhile, the wider world (including the built environment) is experiencing a kind of paradigm shift due to the emergence of the industry 4.0 revolution. Recent technological and other process-based advances and innovative technologies in the built environment mentioned above have a key role to play in this process. As widely reported in the popular and scientific media, the nine pillars supporting Industry 4.0 are 1) The Internet of Things, 2) Big Data, 3) Augmented Reality, 4) Advanced Visualisation, VR and Simulation, 5) Additive Manufacturing, 6) System Integration, 7) Cloud Computing, 8) Autonomous Systems, and 9) Cybersecurity.

In case of the built environment sector, these nine pillars can be said to be underpinned by BIM, widely regarded as the tool of choice to address key issues as industry fragmentation, value-driven solutions, decision making, client engagement, and design/process flow to name but a few. Therefore, it could be argued that the Construction 4.0 has ten pillars which includes the nine Industry 4.0 pillars and BIM. Exemplars from other industries such as automotive, aerospace and oil and gas currently demonstrate the power and application of these technologies. However, built environment has only just started to recognise terms such as "golden key" and "golden thread" as part of BIM processes and workflows. Construction 4.0 offers a portfolio of potential solutions to bridge the knowledge and information gaps between design, construction and operations (Newman *et al.*, 2020; Sawhney *et al.*, 2020).

This has led to the emergence of a series of cutting edge technologies in the AEC realm including but not limited to virtual reality-based collaboration technologies (Pour Rahimian *et al.*, 2019), artificial intelligence-based optimisation (Pilechiha *et al.*, 2020), data-driven decision support (Seyedzadeh *et al.*, 2019), smart data modelling (Pilechiha *et al.*, 2020),

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blockchain and distributed ledger technologies (Elghaish *et al.*, 2020), and computer vision and graphics (Moshtaghian *et al.*, 2020; Pour Rahimian *et al.*, 2020). Where for example, these advancements are now able to assist decision-making to predict the cost and performance of optimal design proposals (Elghaish and Abrishami, 2020b).

Advancements in cryptography and read-only data management optimisation are paving the way for fully-fledged distributed ledger technologies for digital twinning and asset lifecycle management. Previous research has demonstrated real-time centralised solutions for OpenBIM. Collectively, these developments are forcing a paradigm shift in design from asynchronous to real-time data exchanges which are impervious to repudiation, ultimately improving interorganisational perceptions of social presence (Oliver, 2019) and imbuing confidence in the design shift expected of OpenBIM.

This special issue of ECAM brings together eight papers on Construction 4.0 relates topics. These papers are drawn from papers presented at the 36th Annual Conference of the CIB W78 which was held in September 2019 at Northumbria University in Newcastle-upon-Tyne in England. Ghosh *et al.* (2020) sought to identify and rank the perceived importance level of principal research areas associated with the IoT and the construction industry. Abrishami *et al.* (2020) addressed the integration and automation of the whole design and implementation process as a pivotal factor in construction projects. Kamunda *et al.* (2020) identified the fragmentation and inefficiency in the UK water industry project delivery processes which can be addressed by harnessing the collaboration that BIM in Water Industry: Addressing challenges to improve the project delivery process. Keskin *et al.* (2020) systematically analysed how building information modelling (BIM) transforms complex infrastructure settings (i.e. airports) around digital technologies by enhancing connectivity and collaboration between major stakeholders and construction technology solutions in airport project delivery within BIM-centric construction technology ecosystems. Elghaish and Abrishami (2020a) presented an integration of several methods to support automating risk/reward sharing amongst project parties thus enhancing IPD core team members' relationship by proposing a centralised cost management system and exploiting EVM and ABC within IPD. Charlton *et al.* (2020) suggested that the adoption of building information modelling (BIM) in managing built heritage is an exciting prospect, but one that presents complexities additional to those of modern buildings. Qian and Papadonikolaki (2020) examined how trust is affected by the introduction of blockchain technology in construction supply chain management in shifting trust in construction supply chains through blockchain technology. Getuli *et al.* (2020) proposed that process management models and information visualization techniques such as building information modelling (BIM) and virtual reality (VR) seem to be contribute to the advancement of the current safety management practices and propose a safety training protocol based on BIM-enabled VR activity simulations.

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