Guest editorial

Offsite manufacturing: industry transformation and future landscape developments

Offsite manufacturing (OSM) continues to gain traction and momentum, with significant growth patterns predicted over the next three–five years. However, although a number of studies have explored the impact of OSM on organisations and the concomitant market, more often than not, the foci has been to present "process" or "technological" solutions to meet clients' requirements at local, national or international levels. Although it is argued that this in itself provides significant value to the broader debate, it could equally be proffered that this could also prevent wider reflection by using a somewhat myopic lens, as this (*inter alia*) could stifle innovation *per se*, by missing real opportunities and lessons learned from other sectors and industries that have already faced similar challenges. Given this, it was considered important to recognise the success that radical digital transformation can have on organisations – most notably embraced by such pioneers as Amazon, Google, Netflix and Tesla (to name but a few). In this respect, it was also considered important to reflect on the Forbes annual "World's Most Innovative Companies", which provides additional insight on how companies can maximise their "innovation premium". One recurrent question remains "where is architecture, engineering and construction on this list?"

Globally, architecture, engineering and construction (AEC) has been continuously criticised for its performance in relation to other sectors. Part of these challenges have been attributed to high levels of fragmentation and discontinuity, citing the need to conjoin solutions to support integration and interoperability. Although these issues have been presented in several government and industry reports – for example, in the UK from 1934 onwards – but some might argue that these issues resonate with challenges presented in the 11th century (or earlier). Notwithstanding this, it is clear that OSM could be considered a viable solution for addressing some of these issues, particularly with the advent of Construction 4.0, artificial intelligence, machine learning, distributed ledger technologies and OpenBIM solutions.

Being ever-optimistic researchers in the field of AEC, we are often tempted to describe the expected emergence of significant advances in our industry, with phrases that include "in another five years" or "within the next decade". However, with OSM it could be argued that we have already arrived, having passed through the times of "early adoption" (early adopters) or the ubiquitous stops and starts associated with things that are considered new to us. That being said, on observation alone, recent growth in the adoption, uptake and implementation of OSM and supporting technologies has been significant, prolific and some might say "game-changing". Paradoxically, it is argued that we are now way beyond the tipping point. For example, there are a number of OSM solutions (and derivatives thereof) being offered in the market, the offerings of which leverage new approaches, ventures and initiatives – all of which coalesce to provide innovative conjoined solutions between "conventional" approaches and technologies. These actively blend/incorporate new advanced manufacturing opportunities – most of which seamlessly filter down through the supply chain. These benefits are increasingly being recognised, particularly with OSM's capacity of being able to deliver rapid built infrastructure responses in the face of various societal challenges (natural disasters, pandemics, mass housing needs, etc.). These benefits are also underpinned by increased levels of surety concerning end-product

Construction Innovation
Vol. 21 No. 1, 2021
pp. 1-4

1471-4175
DOI 10.1108/CI-01-2021-154

deliverables, which now more naturally includes verifiable processes, with corresponding underpinning value metrics (waste, efficiency, carbon, time, safety, skills availability, cost etc.). More importantly, perhaps, is the wider recognition by the OSM community that things are still evolving, especially given the need to embrace OSM as a unique ecosystem within the wider circular economy. Biomimetics is a good exemplar here. There is also a strong body of OSM communities now gaining prominence and traction, reflecting members' needs for additional support information and knowledge. These include the development of standards and codes of practice, the establishment of bonds of innovation, new specifications and regulatory compliance, proprietary legal and contractual frameworks and the support for project funders/financers – including insurance/sureties and risk (to name but a few).

Acknowledging the above, OSM companies are now uniquely placed to take advantage of these opportunities. In fact, many are already doing so, with several proprietary systems now evolving, which are also changing (challenging) the status of "traditional" economic push–pull force models often associated with client-demand scenarios. Moreover, several breakthrough companies (pioneers) are now exclusively exploiting their core expertise through such avenues supported by specialist platform delivery variants, including bespoke Design for Manufacture and Assembly strategies, hybrid concurrent engineering approaches or unique combinations of "precision engineering" and "restorative intelligence". In short, OSM has now reached a level of maturity where further opportunities can now be exploited. Borrowing the term "visioneering" (Etymology: combination of "vision" + "engineering") for one moment, this promises to open up new and exciting opportunities for all. For example, this inertia is likely to include new working methods, ways of thinking and paradigms – transcending "conventional" approaches to challenge the "status quo". This is likely to include unlocking OSM's true growth potential; delivering new strategic options through sustainable and resilient business models; creating enhanced value propositions underpinned by clear evidential chains; and delivering viable conduits, which meaningfully support the circular economy. Initiatives have already been brought to market, which actively embrace socio-technological and social conscience solutions. Typical OSM exemplars often embrace variations using advanced 3-D printing, smart objects, digital twins, big data, 5G, the Internet of Things – to name but a few. These developments and initiatives will undoubtedly keep "us on our toes" for a while; particularly, how we apply these new technologies, approaches and ways of thinking – to not just solve our current challenges but also open up further research streams for future uptake.

The origins of this special issue initially emerged out of CIB W121 (Offsite Construction). The original call for papers invited OSM cutting-edge research and "lessons learned" from industry, academia, research communities and professional bodies. The rationale of this was to showcase best practice and developments regardless of topic area, supported by conceptual, theoretical or "proof of concept" frameworks and platforms. Emphasis was therefore placed on issues that considered real impact, reach and significance, which, by default, included the means for engagement and delivery. In this respect, we invited topics across a wide range of cross-cutting themes – from additive manufacturing and innovative building systems, through to new delivery platforms and resilient business models. Given these challenges, this special issue presents seven papers for discussion, a brief synopsis of each follows.

Stehn *et al.*'s paper "Understanding industrialised house building as a company's dynamic capabilities" provides a detailed temporal analysis of industrialised house building (IHB). A case study approach was used to capture and analyse original data and archival material over a 25-year period, including retrospective reflections from owners and managers. Findings highlighted the importance of establishing higher-order dynamic capabilities to be able to fully exploit IHB opportunities.

Grenzfurtner and Gronalt's paper "Continuous improvement of the industrialised housebuilding order fulfilment process" presents a reflection on IHB, focussing exclusively on the need to secure a deeper understanding of continuous improvement by incorporating targeted employee knowledge. A case study approach was adopted by using empirical data from participant observation, interviews and company documentation. Findings presented a series of improvement measures and factors needed to support company performance management systems, embedded employee engagement and wider organisational learning constructs.

Killingworth *et al.*'s paper "'General contractors' experience using off-site structural framing systems" explored general contractors' experiences of using off-site manufactured structural framing systems. This engaged domain experts from the mountain-west region of the USA to evaluate the benefits and challenges of such systems through a qualitative-based single case study. Research findings identified significant observable benefits (time, waste, costs, safety and logistics), albeit countered by challenges (project parties, off-site framing system, project scheduling, logistics and complicated off-site system design and standards requirements). These findings also included solutions to overcome these challenges.

Vestin *et al.*'s paper "Smart factories for single-family wooden houses – a practitioner's perspective" investigated the impact and implications of Industry 4.0 on the single-family wooden house industry. This adopted a multiple case study approach using two Swedish companies – taking a practitioner's perspective on the content and meaning of smart factories for single-family wooden houses. Findings highlighted 15 components (automation, building site, building system for automation, CAD-program, competitive products, configurator, flow management, generation of digital information for automatised production, production monitoring, product model simulation, product platform, sustainable products, systems integration, training and education and virtual reality) where eight of these (automation and augmented reality, end-to-end engineering integration, simulation and modelling, sustainability, interoperability, technical assistance, personnel training and virtual reality) corresponded to components of Industry 4.0.

Yang and Pan's paper "Automated guided vehicles in modular integrated construction: potentials and future directions" examined the potential of using automated guided vehicle technology in modular integrated construction to realise logistics automation in module manufacturing and transportation. This engaged a three-phase scenario approach (scenario preparation, development and transfer) with primary and secondary data collected through literature, site visits and interviews with relevant stakeholders and professionals. Findings presented scenarios for "smart manufacturing" and "last-mile delivery", which demonstrated how automated guided vehicles could be used to enhance efficiency and productivity in module manufacturing and transportation.

The final two papers by Bendi *et al.*, "Understanding off-site readiness in Indian construction organisations" and "An off-site construction Readiness Maturity Model for the Indian Construction Sector" present a conjoined OSM solution. The first paper presents a discussion on the off-site construction market within the context of India. This collected data from AEC professionals engaged with off-site construction using purposive non-probability sampling. Findings developed a bespoke model for understanding off-site construction readiness – highlighting 17 core variables for reflection. The second paper presents a discussion on the refinement of this readiness maturity model using 15 semi-structured interviews where participants were asked to refine the original variables (specifically for the

Indian context) and define the criteria needed to measure different levels of attainment for each. This was reinforced with additional methodological measures used to validate the maturity levels and associated definitions. Findings culminated in the presentation of a three-level off-site construction readiness maturity model, which highlighted four core factors matched against three corresponding maturity levels.

Mohammed Arif and Jack Goulding
Department of Architecture and Built Environment, University of Wolverhampton, Wolverhampton, UK
Jeff Rankin
Department of Civil Engineering, University of New Brunswick, Saint John, Canada, and
Farzad Pour Rahimian
School of Computing, Engineering and Digital Technologies, Teesside University, Middlesbrough, UK