Forum

Promoting Off-Site Construction: Future Challenges and Opportunities

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Introduction

While manufactured construction can be traced back to approximately 1851 (Gibb 2001), in the last two decades, a resurgence has occurred, which has now started to gain increased popularity and momentum (Arif and Egbu 2010). For example, in the United Kingdom (UK), the off-site construction industry grew from £2.2 billion in 2004 to £6 billion in 2006 (Goodier and Gibb 2007); and the UK is not unique in the adoption of manufactured construction, as different types of off-site construction techniques are quite common worldwide.

However, if off-site construction is to make a sustained positive contribution in the marketplace, research is needed to identify the pervading issues that constrain the uptake of this, or conversely, can promote this in a more reasoned and defendable way, especially taking into consideration the existing societal, cultural, and current business models associated with conventional thinking and practice. Cognizant of this, a task group (TG74) was commissioned by the International Council for Research and Innovation in Building and Construction (CIB). This group had a mandate to lead international research strategy to address theories relating to production and business models within the built environment disciplines; it was also tasked with developing an off-site built environment research roadmap for construction. This paper presents preliminary findings of a TG74 workshop that focused on identifying the core drivers, variables, and strategic priorities facing the construction industry in the short to medium term.

CIB Background and Task Group 74

CIB is the acronym of the French (former) name Conseil International du Bâtiment (in English this is International Council for Building). The name CIB was revised in 1998 to International Council for Research and Innovation in Building and Construction but the acronym CIB was retained. CIB was set up in 1953 with funding from the United Nations with a mandate to stimulate and facilitate international cooperation and information exchange between governmental research institutes in the building and construction sector. Currently, it has 500 organizations as members and 5,000 experts from these organizations who participate in the research activities of CIB. CIB addresses issues related to current areas of research in the building and construction sector with the formation of task groups and working commissions. These task groups and working commissions act as platforms for researchers and practitioners to exchange ideas. The funding of these task groups and working commissions is the responsibility of members participating in them.

Background for the Workshop

TG74 is a task group consisting of researchers, academics, and practitioners associated with manufactured construction research, teaching, and practice. The purpose of this workshop was to develop the research agenda for off-site construction, with a particular emphasis on short- to medium-term (0–10 years) priorities. In this respect, the TG74 presented a nine-item agenda framework for discussion (see Table 1), the rubrics of which had been developed over the course of six months with leading domain experts and membership participants of TG74. The individuals who led discussions on individual areas are listed in Table 1 below.

Within the context of off-site construction, each of the three major areas of process, technology, and people were analyzed for their impact on design, manufacturing, and construction. The findings from this workshop would help inform strategic thinking, leading to the development of a research roadmap for off-site manufacturing. This paper presents the results of this workshop.

The initial nine areas proposed for the workshop were developed over a period of six months with academics and practitioners. This culminated in three online conference validation sessions hosted over the Internet. These conference sessions were used to garner international focus and establish core priority areas for the in-person workshop session. Individuals participating in these workshops were located in the UK, Scandinavia, Germany, and Australia. The results of this in-person workshop are presented in this paper.

Specific topics identified in these nine areas through online workshops were:

Design technology:

- Technology embedded in the product (in the factory);
- Technology underpinning the business process;
- E-readiness of organizations (and the supply chain): holistic implications on the business;
- Building information modeling (BIM) for off-site (product and process): potential to exploit.

Manufacturing technology:

- Justifiable automation: how much is enough? (e.g., optimization, business case, payback);
- Product and process design: design for manufacture (DIM) (software and systems development, decision support system, integrated product delivery, etc.);
- Supply chain management: manufacturing resource planning (MRP) and enterprise resource planning (ERP) expensive (inflexible and somewhat limited);
- Modeling and simulation: training needed (e.g., systems analysis, discreet event simulation, and modeling).

J. Archit. Eng. 2012.18:75-78.

Table 1. Workshop Agenda Items

	Areas		
Categories	Design	Manufacturing	Construction
Process	Dr. Wei Pan (University of Plymouth, UK)	Prof. Mark Sharp (AIPP, UK)	Dr. Wei Pan (University of Plymouth, UK)
Technology	Prof. Mustafa Alshawi (University of Salford, UK)	Dr. Mohammed Arif (University of Salford, UK)	Prof. Jack Goulding (University of Central Lancashire, UK)
People	Prof. Jack Goulding (University of Central Lancashire, UK)	Dr. Mohammed Arif (University of Salford, UK)	Dr. Malik Khalfan (RMIT, Australia)

Design process:
- Adding value to the business process (multiple perspectives);
- Process protocol: lifecycle processes, tried and tested (concentrate on the most important ones);
- Stakeholder analysis is needed;
- Understand the impact of design and process (with business and technology).

Technology construction:
- Need to understand what information is created, used, and exchanged (e.g., product modeling ontology, W3C): common tools from different vendors (integration and interaction). Granularity of product data could be used better—detailed information, e.g., installation, storage, size, mass, lifting requirements, health and safety issues. (BIM is important here.) Risk needs to be understood more, e.g., existing product/process in established application areas;
- Existing product/process in new application areas;
- New product/process in established application areas;
- New product/process in new application areas as all carry different risk.

Manufacturing process:
- Procedures need to be defined to cope with the variables: will a one-size-fits-all model work?
- Need to look at other industries regarding their business models (not just efficiency over productivity, but also pre- and postoccupancy);
- Integration of suppliers into companies needed (and teams). What would a business model look like? Sustainable business models can be flexible (and business concepts could also be added);
- We have to consider what to adopt and what not to adopt, e.g., automation versus nonautomation (is there a happy medium?). Flexibility needed (variable product line).

Construction process:
- Important to consider business models: which ones, what remit, e.g., house builders, small and medium enterprise (SMEs) (more than 100 systems and 500 suppliers)? How can integration be achieved [through radio frequency identification (RFID)]?;
- Performance of process: hard data needed (e.g., cost-benefit analysis);
- Interfaces between off-site production (OSP) and manufacturing (do we have the right skills?). Focus on UK or overseas? (Global agreed.) Emphasis on on-site or off-site construction? 5-year, 10-year roadmap (up to 2050 agreed). Flexibility needed with elements of standardization (economies of scale).

Manufacturing people:
- Multidisciplinary or interdisciplinary? Mindset training needed (look at projects rather than products);
- Decisions have to be modeled in an integrated way (i.e., incorporating risk);
- Shop-floor approach needs to change and benefits need to be made clear;
- Link to disaster management? Haiti house? (along with cultural issues);
- Mass customization—service parts (how to address the markets);
- Job roles and functions need redefining. Integrating people into the model.

Design people:
- Traditional versus nontraditional: new ways of working require new skills (especially product modeling), new thinking, greater collaboration, reassessment of discipline areas, change in individual and company behavior. Online teaching and learning needed (industry and academia collaboration);
- New approach needed to design (i.e., key unique selling plants (USPs) need to be sold regarding suppliers, assemblers, transport operations);
- Design for manufacture and assembly is an important part of this, along with logistic integration into the design process;
- ManuBuild (design process, manufacturing process, construction process, sales office): link to the supply chain and the customer ("buy-in");
- Product catalogs, smart connections, etc., are available.

Construction people:
- Upskilling of personnel:
  1. So that a site labor or a new person to the industry could work in the factory;
  2. So that site labor knows how to install prefabricated products and modules on site (this would require training/investment);
- Healthy and comfortable working conditions could be a key USP (e.g., health and safety, better working environment, standardized production system);
- Sustainability: social benefits, continuity of employment, economic: stable and long-term employment, transportation: pick zones (i.e., reduced emissions);
- Productivity: e.g., greater efficiency and productivity, no weather disruptions;
- New workforce: greater attraction because of better working conditions, resolution of unskilled labor, no age limit or prerequisite skills for entering the sector.

Workshop

This workshop was hosted at the University of Salford (UK) on November 26, 2010, and was led by two task group coordinators. Workshop participants included four practitioners and ten senior academics. The practitioners occupied senior positions in industry, such as the chief executive officer, head of research and development for a manufactured construction company, head of project management of a large construction company, and a senior partner from a leading consultancy firm. The academics represented all levels of positions from professors through to lecturers (assistant professor), all of whom were active in different areas of manufactured construction. Participants to this workshop were mostly individuals with significant track records in this area and most of them had been active in previous online workshops and task group activities. The individuals had accomplished track records in research and practice in this area and had volunteered to

J. Archit. Eng. 2012.18:75-78.

participate. The participants were given a presentation on the nine different areas to be covered, and were then separated into two groups. Each group had a mix of academics and practitioners, and one member of the group was assigned as the team leader and facilitator. The role of the facilitator was to guide discussions around the nine identified areas in order to achieve consensus. The groups were given 45 min to break out into different sessions and discuss these issues. Groups were asked to develop a consensus on the importance of different areas of research and their impact. This breakout time was to be utilized to share personal views and then arrive to a consensual position in terms of importance and weightage. The facilitators were asked to take notes and present the findings after the breakout sessions were over and all the participants were brought back into the same room.

Discussion

The first area covered during discussions was design technology. Both groups were of the view that this was an important area. However, in order for organizations to implement this effectively, they needed to have a good understanding of the design process. While building information modeling (BIM) has been gaining popularity in the last decade, there was acknowledgment that to effectively implement BIM, it was also important to establish appropriate processes, communication links, hardware and software structures, and suitably train people to use these new technologies. Therefore, only after meeting all these prerequisites could effective design technology implementation occur. Participants did, however, feel that given the current emphasis on sustainability and the ability to simulate different design parameters using design technology, this factor should be at least given a medium priority in the short to medium term.

The second topic discussed was manufacturing technology. Both groups felt that building houses was different from building cars, given the customized nature of manufacturing. It was therefore quite reasonable to automate production lines as several million of the same model cars can be manufactured. However, when it comes to manufacturing buildings or houses, there needs to be inherent flexibility built in to accommodate customized design variances. Therefore, a high level of automation seemed infeasible for manufactured construction; however, a justifiable level of automation or mechanization could be implemented. Therefore, the group felt that this should be recorded as low priority in the short to medium term.

The third area covered was construction technology. This was perceived to be critical to the development and progress of the area of manufactured construction. Effective interaction with manufacturing and design, and technologies that facilitate this interaction, along with providing deeper insights into the implications of decisions, were deemed pivotal. It was noted that there needed to be an effective mechanism in place that could assess the risks associated with use of new construction technology and its interaction with manufacturing and design. Given the importance that construction technology has in the overall success of manufactured construction, this was therefore rated as a high priority in the short to medium term. In this respect, it was felt that more research was needed in this area to identify the variables that could have an impact on the effective implementation of construction technology.

The fourth area discussed was the design process. This area was also identified as being critical, as core processes under the umbrella term of design for X (DFX) which incorporates philosophies such as design for manufacture (DFM) and assembly, design for constructability, and design for sustainability. It was therefore felt that this should be promoted; however, in order to add value to the overall construction/production process, it was important to acknowledge the value added by different members of the supply chain. Therefore, these values could be incorporated at the design phase itself and the overall success of the project could then be decided upon based on the achievement of these values. Given the involvement of more parties in manufactured construction compared to traditional construction, it was therefore perceived to be important that all the stakeholders be involved in the project right from the design phase itself. In addition, more effective implementation of concurrent engineering practices could be engaged to facilitate the effective design process. This area was therefore rated as a high priority.

The fifth area covered was manufacturing process. In this respect, participants recognized the importance of understanding the manufacturing process. Specifically, manufacturing can be very effective in mass production scenarios; however, given the customized nature of the construction industry, a completely different manufacturing paradigm is needed that overtly incorporates design flexibility. It is therefore imperative that the manufacturing processes start providing inputs right at the beginning of the design process. Conversely however, the manufacturing processes need to be more flexible in order to accommodate design changes, engaging a system traditionally referred to as a job-shop scenario in manufacturing literature. To maximize this, a streamlined value-based manufacturing process is needed to derive the maximum benefits out of manufactured construction. This area was also highly rated by all the participants.

The sixth area covered was construction process. It was noted that the construction process in manufactured construction could be reduced to replicate an assembly process. However, this was a very different way of putting together a building, where large components and modules are assembled like toy blocks. The traditional construction process often requires component connection and assembly on site rather than through preassembly often engaged on the manufacturing floor. Therefore, what is needed is a complete rethinking of the construction philosophy, processes, and practices. In this respect, construction professionals need to be retrained to think differently in order to approach a project with a new mindset that synchronizes processes and activities with the manufacturing and design team from a very early stage. This category was rated high because the consequence of this transcends the traditional/manufacturing-process conundrum.

The seventh area covered in the workshop was design people. Both groups were of the opinion that there was a need to retrain architects and designers to maximize benefits. For example, training in DFX and DFM approaches can offer new ways and insights not normally captured through traditional methods. This could help achieve component standardization and reduce design variability, which would make manufacturers' business models more viable while offering greater flexibility to constructors. This new thinking also mirrors the traditional architectural philosophy that form follows functionality, which is now more true than ever, especially as functionality also includes manufacturability and constructability and not just functionality postoccupancy of the building. This area was therefore rated as a high priority.

The eighth area covered was manufacturing people. It was generally accepted that personnel within the manufacturing sector were readily familiar with both mass customization as well as customized one-job scenarios. Therefore, embracing variations to meet new sector requirements would not pose too much of a challenge. However, it was noted that terminologies and processes would need to be communicated differently, so that design and construction personnel could liaise more effectively with manufacturing

J. Archit. Eng. 2012.18:75-78.

Table 2. Summary of Priority Identified

Categories	Areas		
	Design	Manufacturing	Construction
Process	High priority	High priority	High priority
Technology	Medium priority	Low priority	High priority
People	High priority	Medium priority	High Priority

personnel. For example, coordination is particularly important not just with the design team but also with the construction team, as there is an exigent need to ensure that construction site and construction approaches are dovetailed to meet the manufactured components and logistics rollout schedules. This area was assigned a low- to medium-level priority.

The ninth and final area covered was construction people. One of the key benefits of manufactured construction is the potential to reduce site waste. Given the current emphasis on sustainability, it was therefore deemed important that construction personnel were made aware of these benefits. This, however, would require retraining and reskilling of operatives in the practices of manufactured construction in order to harness the benefits of waste reduction. Further positive impacts were also acknowledged if manufacturing schedules were linked to actual construction processes, so that storage and double handling can be minimized. Therefore, greater manufacturing awareness would be a natural part of this upskilling and retraining so that processes are holistically managed to leverage potential benefits. This area was therefore rated as a high priority.

The summary of findings based on these discussions is documented in Table 2.

Conclusion

This workshop highlighted several key issues within the nine designated areas. The core message emerging from this workshop is that processes in design, manufacturing, and construction have to be completely reengineered in order to harness maximum benefits from the manufactured construction. However, this mandate requires people to be retrained, especially design and construction personnel, and manufacturing people need to liaise and interact more closely with design and construction personnel. As far as technology is concerned, given the customized nature of manufactured construction, it was also noted that there was a need to embed greater design flexibility into the manufacturing floor in order to better meet stakeholder needs. Finally, while greater automation within manufacturing was beneficial, it was considered more important to focus on value-added activities such as visualization and simulation technologies. Findings of the workshop will facilitate research and more in-depth analysis of individual areas and topics within them. These findings can be used by researchers as starting point of their future research. The detailed workshop report will be published by CIB and distributed to all its members. CIB could also consider extending the tenure of this task group to investigate issues identified further.

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