Building Off-Site

By Robert Hairstans, PhD

Off-site construction, the manufacture and pre-assembly of construction components, elements or modules in a factory before installation into their final locations, continues to show steady growth across the globe. Already well-established in North America, Europe, Japan, Australia, New Zealand and Malaysia, the sector's most prominent emerging markets are China and India. This global growth is a result of several interrelated factors, including new quality thresholds, improved customer perceptions, government-support initiatives and the success of various high-profile case studies.[1]

The off-site construction sector consists of four main categories: panelized, modular/volumetric, hybrid and sub-assemblies/components[2][3] (*see "Figure 1," below*). If required, they can be further broken into additional subcategories (*see "Figure 2," opposite page, top*). Additionally, a range of key terminologies describes off-site construction (*see "Table 1," opposite page, bottom*). A "Glossary of Off-Site Construction Terms" also is available from the National Institute of Building Sciences Off-Site Construction Council.[4]

A Different Approach

When compared to on-site construction, off-site construction constitutes a change of approach: Off-site normally requires a factory in a fixed location served by good transport links. Within a factory, the environment can be more controlled due to standardization, mechanization and automation. In addition, the off-site approach changes the operational dynamic, requiring increased levels of project management for such concepts as design for manufacture and assembly (DFMA) and design freeze. DFMA is the concept of designing products and systems that are tailored for ease of manufacture, transport and assembly. Therefore, it is important to understand the available supply-chain components, manufacturing-process capabilities, logistical arrangements and any on-site restrictions. In this respect, it is important to "freeze" the design early, given the level of project interdependencies. Late changes are more difficult to rectify, however, given the need to interface off-site built systems with on-site tolerances (such as foundations, which are pre-established to save project time).

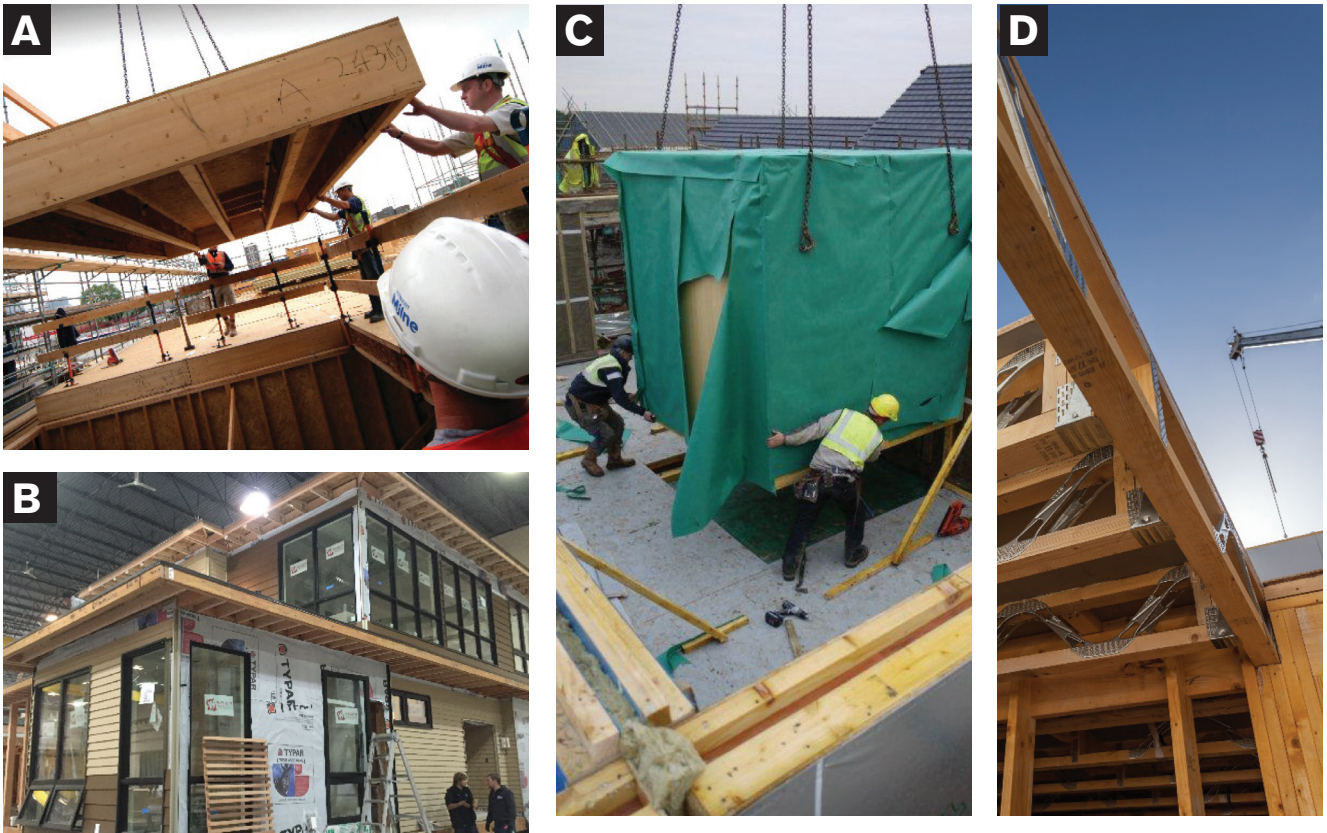


Figure 1: Forms of off-site construction include a) panelized 2-dimensional (2D); b) modular/volumetric 3D; c) hybrid 2D + 3D; and d) sub-assemblies and components.

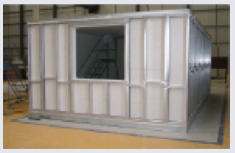
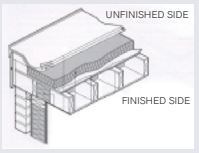
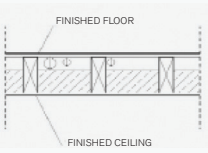
SUBCATEGORIES	CATEGORIES: 2D Elements – Walls	2D Elements – Floors	2D Elements – Roofs	3D Modules
0	 Uninsulated open panels with first skin only on one side (e.g., oriented strand board—OSB—on one side of timber panels)	 Uninsulated floor panels with decking only on one side and exposed joists/beams	 Uninsulated open panels with first skin only on one side (e.g., OSB on one side of timber panels)	 Uninsulated modules whose surfaces have first skin on only one side
1	 Insulated open or closed panels without finished linings (e.g., structural insulated panels—SIPs)	 Insulated floor panels without finishes	 Insulated open or closed panels without finished linings	 Insulated modules without finished linings
2	 Insulated closed panels finished on one side (either internally or externally)	 Insulated floor panels finished on one side (either upper or lower side)	 Insulated closed panels finished on one side (either internally or externally)	 Insulated modules with finished lining on one side (either internally or externally)
3	 Insulated closed panels fully finished externally or internally, with integration of services (i.e., with electrical and mechanical services, windows and doors)	 Insulated floor panels fully finished on the upper and lower sides, with integration of services (i.e., with electrical and mechanical services)	 Insulated closed panels fully finished externally or internally, with integration of services (i.e., with electrical and mechanical services, windows)	 Modules fully finished on all sides, with integration of services (i.e., with electrical and mechanical services, windows and doors)

Figure 2: Subcategories of off-site construction.

Due to these various moving pieces, off-site construction requires enhanced levels of security and a change in the emphasis on skill requirements. However, off-site can offer higher levels of value in terms of quality assurance and corresponding customer satisfaction through time and cost certainty. Also, off-site systems often are more technically advanced due to the inherent quality assurance (QA) process of a factory environment and the use of lean production concepts. (Lean production, which stemmed from the production system at Toyota, represents striving for perfection through a continuous improvement process. Lean principles encompass teamwork, robust communication, efficient use of resources and elimination of waste.)

Beyond cost efficiencies, off-site offers a more sustainable approach to construction. Socially, the factory environment improves working conditions and offers a change in "construction culture" by providing a safe, clean place of work with improved job security and flexible shift patterns. This is of particular relevance when considering staff diversification. In the Government of the United Kingdom (UK), for example, women account for only 13 percent of total employment in the construction sector. However, women fill 27 percent of off-site roles due to better security and greater flexibility.[5] From an environmental perspective, "constructing" off-site in a factory corresponds to a more-efficient use of materials. A qualified supply chain secures this efficiency since these materials then can be optimally utilized to create components that are assembled on-site to form enhanced levels of building performance. In addition, off-site offers wider economic advantages; specifically, it provides opportunities for up-skilling a local labor force, which adds value to a localized supply chain in the efficient delivery of a higher-quality product. Off-site construction can offer

Continued on page XX

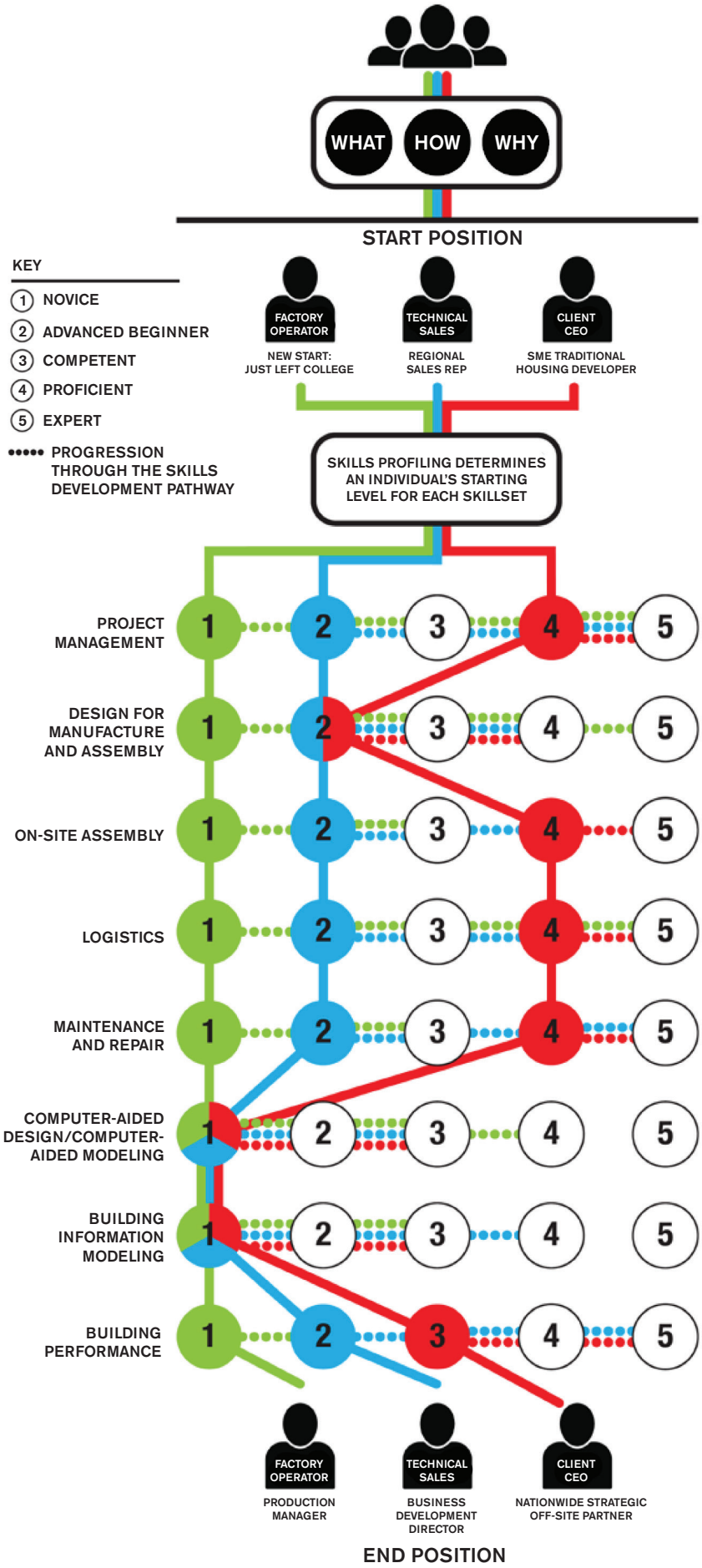


Figure 3: Examples of off-site skills development pathways.

significant financial benefits through increased speed of construction and consequent reductions in financing costs. Early project completion and a consequent early sale/rental income also provide significant cash-flow opportunities.

Addressing Resistance

Although a compelling case exists for off-site construction, industry players may resist such a change, mainly due to the different skillset requirements. Off-site needs a more-holistic knowledge base with an improved understanding of project management, scheduling and planning requirements. Given this, all levels of off-site need a new approach to training and skills in order to improve pathways for career progression and enhanced levels of up to-date information (*see "Figure 3," page XX*). In addition, the higher levels of capital and technical approval costs for off-site construction require more-informed investment decisions and a more robustly defined value proposition through improved levels of evidence-based information. In this respect, off-site construction requires strong business leadership, combined with operational management and technical knowledge, to address misconceptions of the public, clients, lenders and insurers. Addressing these also will challenge the traditional construction business models since off-site has a different cash-conversion cycle, e.g., more upfront costs, which require different finance arrangements for it to operate at scale.

A need for improved levels of guidance and information[6] are necessary, too, because off-site is closely associated with manufacturing and draws on principles that seek to improve quality, efficiency and waste reduction. The guidance required and flow of information among design, production and assembly are, therefore, different from traditional construction. These communication channels require more integration and more-holistic knowledge at all levels. For example, off-site often is criticized for a lack of design flexibility. Through a well-defined product family architecture (PFA), however, it can ensure the desired levels of variation to suit customer/client needs. PFA is a

range of standardized component parts used for a mass customized design approach, often contained within a computer-aided design (CAD) library for design efficiency. Mass customization is the fulfilment of customized requirements at an industrial scale utilizing standardized components in order to achieve competitive prices and lead times.

Improvements in information and communication technology (ICT), including the onset of building information modeling (BIM), should assist with the adoption of off-site techniques. By visualizing 3-dimensional (3D) computer models, BIM should help with the control of information, from conceptual design to on-site interfacing. Furthermore, it should help demonstrate the value proposition of off-site through the representation of robust data acquired on time, cost, technical and overall environmental performance (embodied and operational energy).

Based upon the evidence available, the barriers to off-site construction internationally have relative commonality.[1][6][7][8] In this respect, improved

Continued on page XX

Term	Overview
Prefabricated (Pre-Fab) Construction	Prefabrication can cover off-site prefabrication of materials and parts; prefabrication of components and subassemblies; and volumetric units or modules.
Modular Construction	Modularization of construction is considered a way of reducing complexity but still offering customized solutions. The Modular Building Institute (MBI) defines modular construction as an off-site process, performed in a factory setting, yielding 3D modules that are transported and assembled at a building's final location.
Industrialized Building Systems (IBS)	IBS represents the prefabrication and construction industrialization concept. The term has been used as a shift away from prefabrication, with additional emphasis on improved productivity, quality and safety.
Open Building Manufacturing	Open building manufacturing is the concept of applying production theory to construction, employing standardized components that can be configured and assembled to provide a specific end result.

Table 1: Key off-site terminologies.

levels of international knowledge management are opportunities to collectively overcome these barriers.

A recent workshop, held in Boston by Offsite Construction International and co-hosted by the University of Utah, Edinburgh Napier University (Scotland) and Lulea University of Technology (Sweden), served to progress an international, industry-led conversation. The findings from this workshop, which were supported by the National Institute of Building Sciences, Scottish Enterprise, Scottish Development International and The Construction Scotland Innovation Centre, will be presented and taken forward at the 2016 Modular and Off-site Construction (MOC) Summit. Learn more at **www.mocsummit.com**. JNIBS

ABOUT THE AUTHOR: Robert Hairstans, PhD *is head of the Centre for Offsite Construction + Innovative Structures (COCIS) at Edinburgh Napier University (Scotland), Institute for Sustainable Construction (ISC) and lead author of* Building Offsite: An Introduction*, which is available free at* **www.constructionscotland.org.uk/offsite**.

References:

[1]Goulding, J.; Arif, M., (2013). "Offsite Production and Manufacturing—Research Roadmap," *International Council for Research and Innovation in Building and Construction* (CIB) Publication 372, ISBN 978-90-6363-076-8 **http://site.cibworld.nl/dl/publications/pub_372.pdf**.

[2]Abosaod, H.; Underwood, J.; Isikdag, U.; Barony, S., (2010). *A Classification System for Representation of Off-Site Manufacturing Concepts through Virtual Prototyping*, 9th International Detail Design in Architecture Conference, location??.

[3]Krug, D.; Miles, J., (2013). Offsite Construction; Sustainability Characteristics, Buildoffsite, UK, **www.buildoffsite.com**.

[4]National Institute of Building Sciences, Off-Site Construction Council, *Glossary of Off-Site Construction Terms*, Washington, D.C., **www.nibs.org/resource/resmgr/OSCC/GlossaryOffSiteConstructionT.pdf**.

[5]Construction Skills, (2009). *Sector Skills Assessment for the Construction Sector*, Construction Skills UK Report.

[6]Smith, R.; Gosskopf, K.; Elliot, J., (2015). "Off-Site Construction: Reaching the Tipping Point," *Journal of the National Institute of Building Sciences*, April 2015.

[7]Smith, S.; Hairstans, R.; MacDonald, R.; Sanna, F., (2012). "Strategic Review of the Offsite Construction Sector in Scotland," *The Scottish Government*, ISBN 978-1-78256-394-5.

[8]Pham, C.; Marie-Claire, D.; Ridoy, S., (2014). "Australian Residential Construction Off-Site Preassembly Road Map: Challenges + Actions, Design Flexibility and Industry Collaboration," University of Sydney, **http://chuckpham.com/OPARoadmap.pdf**.