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Briefing: Bringing clarity and new understanding of smart and modular integrated construction

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Modular construction has been promoted worldwide, with well demonstrated benefits. Modular integrated construction (MiC) was recently established in Hong Kong with the focus on integrated solutions to address high-rise buildings in high-density cities for productivity and competitiveness. Nevertheless, insufficient and inconsistent understanding exists. The University of Hong Kong has recently launched *A Glossary of Modular Integrated Construction*, which defines and illustrates over 170 terms related to MiC, off-site construction and smart project delivery, aiming at synergised understanding. The Glossary brings clarity and new understanding of modular and smart construction to the industry and community. With a focus on future building development in high-rise high-density contexts, the Glossary should become an important aid for achieving wider adoption of modular construction and smart technologies.

1. Introduction

Modular construction has been promoted worldwide with benefits well demonstrated. Modular integrated construction (MiC) was recently established in Hong Kong to focus particularly on integrated solutions for achieving smart project delivery (SPD) and sustainable construction for high-rise buildings in high-density cities. Pan and Hon (2020: p. 65) defined MiC as ‘a game-changing disruptively innovative approach to transforming fragmented site-based construction of buildings and facilities into integrated value-driven production and assembly of prefinished modules, which will realise enhanced quality, productivity, safety and sustainability’.

MiC has been demonstrated with substantial benefits over conventional construction – for example, improved economic efficiency, fortified environmental sustainability and enhanced social harmony (Pan *et al.*, 2020a). Nevertheless, insufficient and inconsistent understanding exists in the construction industry and knowledge community, which hinders the successful and wide adoption of MiC (Pan *et al.*, 2019). Therefore, in December 2020, the Centre for Innovation in Construction and Infrastructure Development of The University of Hong Kong launched *A Glossary of Modular Integrated Construction* (Pan *et al.*, 2020b), with the aim of bringing clarity and new understanding of the industry and community about modular and smart construction.

As MiC represents the most advanced among the many off-site construction (OSC) methods (Gibb, 1999) and is powered by smart technologies (Zhang *et al.*, 2020), this Glossary defines and illustrates over 170 terms in relation to OSC, MiC and SPD, aiming for synergised understanding. This briefing paper aims to

elaborate on the significance and contributions of the Glossary by presenting the three main categories of terms included (i.e. OSC, MiC and SPD) and highlighting the advancements of this Glossary over others in the literature.

2. Category of terms

2.1 OSC-related terms

OSC is defined as the manufacturing and pre-assembly of building components, elements or modules before installation into their final locations (Gibb, 1999). Based on the extent of off-site works, this Glossary categorises OSC technologies into three levels, ranging from materials, components and subassembly through prefabricated non-volumetric pre-assembly and volumetric pre-assembly, to prefabricated, prefinished and pre-furnished modules, where MiC represents the most advanced form of OSC (Figure 1).

Furthermore, this Glossary covers wide-ranging terms that are similar to OSC, such as ‘off-site production/fabrication/manufacturing’, ‘prefabrication’ and ‘industrialised building’ (Gibb and Pendlebury, 2006). The whole collection of OSC-related terms serves as a knowledge base for consistent communication and sharing in the construction industry.

2.2 MiC-specific terms

MiC is powered by advanced structures and materials for the creation of higher and stronger buildings and by smart technologies for quality and efficient project delivery. The MiC-specific terms in this Glossary (Figure 2) include but are not limited to those frequently used in modular design (e.g.

Figure 1. OSC: concept and categorisation

‘modularisation’), project delivery process (e.g. ‘concrete and steel-framed modules’) and relevant regulations (e.g. ‘practice note on gross floor area exemption’).

Furthermore, this Glossary includes diverse terms related to modular construction in the wider context, such as ‘prefabricated prefinished volumetric construction’, established in Singapore, as well as ‘volumetric modular construction’, adopted in Australia. The comprehensive list of MiC-specific terms helps improve the common understanding of the modular approach and should facilitate relevant policymaking and project management in various jurisdictions.

2.3 SPD-associated terms

This Glossary covers a wide range of SPD-associated terms that have been well adapted to MiC/modular construction or have good potential to facilitate quality, safe and efficient project delivery. The selected terms cover wide-ranging technologies mainly residing in artificial intelligence (e.g. ‘computer vision’, ‘deep learning’), Internet of things (IoT) (e.g. ‘ultra-wideband sensors’, ‘cyber-physical system’), robotics (e.g. ‘robot-oriented design’, ‘autonomous guided vehicle’) and digital construction (e.g. ‘building information modelling’, ‘virtual reality’) (Figure 3).

The identified SPD-associated terms together reveal the co-evolution of smart building technologies and modular construction (Yang *et al.*, 2019), indicating the clear trend of digital transformation of the whole industry. Thus, this Glossary should thus encourage the industry and research community to take active steps in exploring and implementing SPD technologies for successful MiC adoption.

3. Discussion

This Glossary contributes a comprehensive collection of terms in relation to OSC, MiC and SPD with cutting-edge prospects on industry development and practical generalisability to different settings. It should therefore advance other glossaries in the literature, which is discussed as follows.

First, this Glossary provides a collection of terms in a more comprehensive and systematic manner than similar glossaries do (e.g. MCCB, 2017). Besides those well-established terms (e.g. modular construction), this Glossary also includes a variety of emerging terms as relevant. For example, the term ‘smart MiC’ is included to promote the implementation of digital, automatic and/or intelligent technologies in the modular project delivery process to achieve high quality, safety, efficiency and sustainability.

Figure 2. Examples of MiC-specific terms: (a) concrete module (courtesy of Yau Lee Wah); (b) steel-framed module (courtesy of China International Marine Containers (Group) Ltd); (c) modularisation; (d) module integrated construction (courtesy of Hip Hing)

Moreover, this Glossary presents a whole list of innovative technologies (e.g. terms in relation to AI and IoT) and their potential applications in MiC, which have never been sufficiently considered in previous glossaries.

Second, this Glossary presents cutting-edge prospects on the future research and development of the construction industry. For example, the term ‘MiC higher’ is included, which describes a future version of MiC involving the exploration of four interrelated themes in the framework of innovating higher: higher rise, higher density, higher tech and higher co-creation. Particularly, ‘higher tech’ promotes the integrated use of technologies such as AI, IoT, automation and robotics to transform digitally the traditional construction industry and thus

further improve construction productivity, quality and sustainability, while ‘higher co-creation’ advocates industry-wide partnership for achieving ‘higher tech’.

Third, this Glossary is generalisable and thus applicable for the construction industry of Hong Kong and other high-rise high-density city contexts and beyond. Specifically, modular technologies used in different jurisdictions are depicted and compared. Furthermore, a number of representative research and development organisations worldwide are identified and provided. This information makes this Glossary an all-inclusive and useful source of information for the global construction industry and research community and supports the application and advancement of modular technologies.

Figure 3. Examples of SPD-associated terms: (a) computer vision (Zhang *et al.*, 2020); (b) Internet of things (Zhang *et al.*, 2020); (c) autonomous guided vehicle (AGV) (Yang and Pan, 2020); (d) building information modelling

4. Conclusions

This briefing paper has introduced the purpose, contents and contributions of the booklet *A Glossary of Modular Integrated Construction*. This Glossary provides definitions of MiC in Hong Kong and related terms worldwide, accompanied by illustrations drawing on the state-of-the-art literature of modular and OSC and SPD. This Glossary should support construction stakeholders in their adoption of MiC by enhancing a comprehensive and consistent body of knowledge. The Glossary should also become an important aid in ensuring maximised benefit from adopting smart and modular construction and leapfrogging the construction industry to the future. By introducing the Glossary, this paper should assist both industry practitioners and academic researchers in quickly understanding the body of knowledge of MiC in a systematic manner.

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