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Exploring the challenges to industrialized residential building in China

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A B S T R A C T

Industrialised building (IB) is considered by many to have an important role to play in China's residential construction industry due to its potential for improved quality, productivity, efficiency, safety and sustainability. It is surprising, therefore, that although a large number of construction programmes have been completed in the country in recent years, very few have been built in this manner. Quite why this situation exists is unknown. The well-known problems with IB, such as the constraints placed on designer freedom, may be the cause. It is equally possible that, as is typical with developing countries such as China, cost or government issues dominate. On the other hand, in comparison with other countries, the construction industry in China has been widely criticised for its lack of modernity. Either way, there is an urgent need to assess and understand the hindrances to the adoption of IB in residential construction in order to identify what corrective measures, if any, need to be taken.

Towards this end, we first identify a set of critical factors (CFs) for assessing the hindrances to IB adoption in China. This involves the analysis of research data collected by a questionnaire survey of experienced housing developers and professionals working in China's construction industry sector. Fuzzy set theory is used in the selection of the CFs. These CFs comprise, in rank order: higher initial cost; lack of skilled labour in IB; manufacturing capability and involvement issues and product quality problems; lack of supply chain; lack of codes and standards; and lack of government incentives, directives and promotion. The establishment of the CFs provides a basis for local construction sectors to better equip themselves for future implementation of IB. The findings also indicate a current need for formulating improved policies and strategies to encourage the further development of IB in China at present.

Introduction

Industrialised Building (IB), where construction components are manufactured in a controlled environment, either at site or off site, placed and assembled into construction works, is considered by many to be a key for improving the construction industry (e.g. Cook, 2005; Hampson & Brandon, 2004) and there have been many studies regarding the implementation of the IB approach and its potential. For example, although some maintain that IB approach is comparatively more expensive than conventional construction methods (e.g. Birkbeck & Scoones, 2005), many studies find that project cost savings due to IB implementation has substantially increased over time (e.g. Goodier & Gibb, 2007; Gibb & Isack, 2003). Recent work has also highlighted the potentially positive role of IB in the introduction of green construction (Jaillon & Poon, 2008; Zhang & Skitmore, 2012).

The industrialisation of residential building construction is one of the most significant developments in recent years, having reached over 50% in developed countries by 2010 (Jia, 2010). Unsurprisingly, therefore, industrialised housing is increasingly becoming a major alternative form of construction in China (Pan, 2007) and the Chinese government has started proactively to promote the implementation IB to meet rapidly growing housing needs. However, while a consensus exists in favour of industrialisation due to its established potential for improving the quality and productivity of building projects, progress in implementation is relatively slow, with under 10% of completed domestic housing projects in the past 10 years being industrialised (Fan, 2010). Even for the China Vanke Group, one of China's largest real estate developers, the level of industrialisation reached only 20% (Qin, 2011).

To date, very few studies have investigated the constraints involved in adopting IB in China. As a starting point, therefore, we seek to bridge the knowledge gap concerning the hindrances

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involved by identifying and examining the critical factors (CFs) needed to assess the constraints on industrialised building. An historical review of the development of IB is first conducted. This is followed by initial identification of a checklist of the CFs needed. Next, a questionnaire survey of experienced housing developers and professionals working in China's construction industry is analysed. Then, through the application of fuzzy set theory, several CFs are selected to evaluate the constraints involved. Finally, important implications and useful directions for future research are identified and discussed.

Literature review

IB, with its stated aim of raising efficiency by rationalising the construction process through the adoption of scientific approaches, is considered by many to have begun in the late 1950s in Japan and adopted later in Europe and North America (Dodgson & Gann, 2010). Although developing at the end of a continuum of possible processes that take different paths in different countries, several specific characteristics reflect IB development in developed countries. Of these, 'standardisation' (Gann, 1996; Lessing, Stehn, & Ekholm, 2005), 'prefabrication' (Dawood, 1996; Gibb, 2001) and 'system building' (Finnimore, 1989; Gann, 1996) are three underpinning attributes that portray the essence of industrialised buildings as follows:

- *Standardisation*: the prerequisite for the factory production of components (Gann, 1996). After World War II, 'modular coordination in building' first aroused the attention of European and North American countries. Then, in the 1960s, the United Nations proposed its 'building modular coordination', setting up standardised criteria for examining component specifications such as performance, structure, tolerance and installation (Milton, 1980).
- *Prefabrication*: involving factory-built components that are assembled on-site to increase the speed of construction and to reduce costs. These components generally comprise two types – those produced directly off-site without knowing the design of the building, and those produced for a specific building with prior knowledge of its design (Gann, 1996).
- *Systems building*: links the prefabricated components with manufactures, involves construction sequencing and a streamlined off-site construction technology service system. System building relies on a well-coordinated development scenario where designers (architects and engineers) work together. For example, there were more than 100 modular factories in Americain the 1970s, forming an integrated, independent industry from design to production. In addition, site handling, site clean up and the demolition of buildings may be commissioned to be undertaken by a specialist organisation (Wang, 2006).

Of these attributes, the first two are the most common. Japan's industrialisation housing, for example, began when the need for homes increased dramatically, leaving the industry with insufficient construction personnel and skilled workers to satisfy demand. In order to simplify site construction and improve the quality and efficiency of the residential product, many building components were standardised for mass production and prefabrication buildings were produced on a large scale (Barlow et al., 2003). As a result, the major building forms in this period included box-style and modular in addition to large residential wall forms. Also, during the 1970s, several large construction enterprise groups, such as the Daiwa House Group, entered the market, contributing to the maturity of the housing industry at that time. By the 1990s, IB accounted for 25%–28% of the total number of residential houses completed, with 1418 components having gained 'good residential parts' certification. In Asian counties other than Japan, such as Singapore, the IB approach was introduced in the early 1980s, involving several prefabrication systems developed by local and overseas contractors (Wong & Yeh, 1985).

In Europe, France was one of the world's earliest countries to implement IB. From the 1950s to 1970s, the 'first generation of building industrialisation' was established, characterised by fully assembled prefabricated panels and an instrumental template situ process (Pan, Gibb, & Dainty, 2007). This was followed in the 1970s by the 'second generation of building industrialisation' to meet the increasing needs of the construction market and characterised by the transitional development of common components and equipment. Later, in 1996, high precast levels were reported in Denmark (43%), the Netherlands (40%) and Sweden and Germany (31%) (Jaillon & Poon, 2009).

IB is very popular in North American countries, where the development of standardisation and system building is very advanced. As residential construction in this region was affected little by World War II, the European large-scale prefabricated approach was not followed, but instead a rather individualised and diversified residential style became the focus. Most of the houses are low-level wooden structures built in the suburbs, designed to accommodate the requirements or specific tastes of homeowners (Fan, 2010). The market then provides the materials, components or any other parts needed. These standardised, serialised component parts are either purchased and installed by the owners themselves or commissioned from contractors on site (Friedmana & Cammalleria, 1993).

The Malaysia Construction Industry Development Board defines IB as a construction technique in which components are manufactured in a controlled environment (on or off site), transported, positioned and installed into a structure with minimal additional site works (CIDB, 2003). This is considered to be of national importance in providing an answer to Malaysia's housing shortage (Badir, Kadir, & Hashim, 2002) and, since 2003, the government has embarked on the programme to promote its by insisting that all public projects must contain 70% Industrialised Building System components (Chuan & Rashid, 2011). However, the System needs a much higher initial capital investment than does the conventional system due to the need to construct production facilities and the high cost of training labour (Badir et al., 2002).

IB development in China has gone through a long and complicated three-stage process as described in the next section.

IB in China

Initial development stage: 1950s–1970s

Research and use of precast concrete structures in China goes back to the 1950s. However, it was only in the early 1970s that prefabricated housing technologies were attempted - mainly focused on learning from the former Soviet Union's large boardroom building technique (Wang, 2006). This kind of building technique enabled the former Soviet Union's central construction agencies to prepare several standard architectural designs to be used by modern factories capable of mass producing precast concrete components ("large blocks") and a series of standard designs for apartment houses to be built by the large panel method (McCutcheon, 1989).

During this period, the Government put forward its "three transformations" of design standardisation, factory production of components and parts, construction mechanisation and wall reform, as a move to ultimately realise the industrialisation goal of