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Schedule risks in prefabrication housing production in Hong Kong: a social network analysis

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ABSTRACT

Various schedule risks beset prefabrication housing production (PHP) in Hong Kong throughout the prefabrication supply chain, from design, manufacturing, logistics, to on-site assembly. Previous research on the risks in prefabrication construction projects has mainly focused on the construction stage and has been confined to issues of completeness and accuracy without consideration of stakeholder-related risks and their cause-and-effect relationships. However, in reality, the supply chain is inseparable as precast components should be manufactured and transported to sites to fit in with the schedule of on-site assembly in seamless connection manner, and most risks are interrelated and associated with various stakeholders. This study applies social network analysis (SNA) to recognize and investigate the underlying network of stakeholder-associated risk factors in prefabrication housing construction projects. Critical risks and relationships that have important roles in structuring the entire network of PHP are identified and analyzed. BIM (Building Information Modeling)-centered strategies are proposed to facilitate stakeholder communication and mitigate critical schedule risks and interactions underlying the risk network. This study not only provides an effective method to analyze stakeholder-associated risk factors and to evaluate the effect of these risk factors from a network perspective, but also offers a new visual perspective in the promotion of the use of the Internet of things (IoT) and helps identify housing construction problems in Hong Kong.

1. Introduction

The balance of housing supply and demand is a crucial concern in Hong Kong, which is one of the most densely populous areas in the world. Hong Kong has an area of 1104 km^2. and an average population density of 6524 persons per sq.km according to the Hong Kong Annual Digest of Statistics 2015 (Census and Statistics Department, 2015). The limited availability of land and expensive land prices have resulted in the prevalence of high-rise building construction in Hong Kong. Only a small percentage of the population can afford the high prices of private housing, with about 50% of the population residing in public housing. More than 100,000 applicants are listed in the Housing Authority, awaiting public rental housing (PRH), possibly for at least seven years before moving into a rental place, given the PRH demand and supply (Chua et al., 2010). Housing issues in Hong Kong have resulted in widespread discontent. In addition, a series of problems and constraints have arisen in the construction industry of Hong Kong, including safety, labor shortage, time, and environmental protection. As a solution to housing problems, prefabrication construction is envisioned to gain momentum in Hong Kong against this socio-economic background, as in the face of the constraints in delivering the housing plan, prefabrication has been increasingly advocated owing to its potential benefits such as faster process, cleaner and safer working environment, and better quality (Tam et al., 2015; Uttam and Le Lann Roos, 2015).

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However, other problems beset the industry of prefabrication housing construction. The processes of design, manufacturing, storage, transportation, and on-site assembly are fundamentally fragmented, nurturing a variety of risks that impose major pressure on the time management of prefabrication housing production (PHP). As a result, delay frequently occurs in PHP despite the promise of the government to meet the high housing demand. To help address these problems encountered in the construction of prefabrication housing, many studies have investigated the risk-related issues in the management of PHP. However, these studies do not consider risks from the perspective of stakeholders, despite these risks being subject to different stakeholders designated to perform different tasks under different construction scenarios. Previous studies also do not sufficiently consider the interrelationships underlying the risk factors and their actual influence on a network basis. Thus, this research proposes a model to evaluate the stakeholder-related risks found in four major prefabrication construction processes, employing the social network analysis (SNA) method. Critical risks and interactions that significantly influence the time management of PHP are identified, and corresponding BIM-centered strategies are proposed to address the challenges encountered in the time management of PHP.

2. Background research

2.1. PHP in Hong Kong

Also called off-site construction, prefabrication construction refers to structures built at a location other than the location of use (Gibb, 1999). The construction of structural parts occurs in a manufacturing plant specifically designed for this type of process, which is typically contrasted to traditional on-site housing production. PHP processes in Hong Kong are summarized in Fig. 1: (a) design, (b) manufacture, (c) cross-border logistics, and (d) on-site assembly. Normally, a client, which is normally Hong Kong Housing Authority in Hong Kong, hires designers for architectural and engineering design, with special consideration given to the adoption of modules and their structural safety, buildability, and transportation convenience. The design information is then transmitted to the manufacturer for the production of precast components. The whole prefabrication manufacturer sector of Hong Kong has been moved to offshore locations in the PRD (Pearl River Delta) region in China, such as Shenzhen, Dongguan, Huizhou, Zhongshan, and Shunde. After the precast elements are produced at the PRD, companies with better coordination can transport the components through Shenzhen–Hong Kong customs and directly reaching construction sites in Hong Kong. Others most of companies have to store their components in a temporary storage in Lok Ma Chau, which is a large area close to the customs facility, for conveyance buffer purpose. Lastly, these precast components are installed by the assembly company to replace the traditional cast in-situ work. Unlike the processes in conventional cast in-situ construction, prefabrication housing is considered to be a significant process innovation that can greatly facilitate housing production as it allows: (1) compressed project schedules that result from changing the sequencing of work flow (e.g., allowing for the assembly of components offsite while foundations are being poured on-site; allowing for the assembly of components offsite while permits are being processed) (Tam et al., 2007); (2) more controlled conditions for weather, quality control, improved supervision of labor, easier access to tools, and fewer material deliveries (Mao et al., 2015; Ingrao et al., 2014a, 2014b); (3) fewer job-site environmental impacts because of reductions in material waste, air and water pollution, dust and noise, and overall energy costs (C. Tam et al., 2005; Li et al., 2015; Tam and Hao, 2014; V.W. Tam et al., 2014; Hong et al., 2016), and (4) reduced requirements for on-site materials storage, and fewer losses or misplacement of materials (Li et al., 2014a, 2014b; Wang et al., 2015).

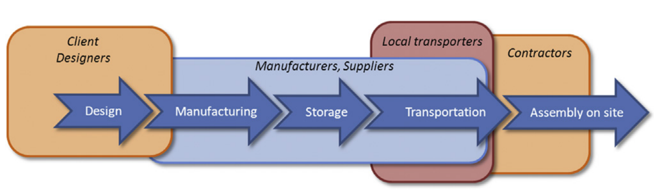

Fig. 1. Prefabrication housing processes.

2.2. Stakeholders and schedule risks in PHP

In recent year, the view of PHP project success has transformed from achieving the specific indicators such as safety, cost, quality and time towards a human-based perspective of achieving stakeholder satisfaction. Nevertheless, stakeholders have different interests in and therefore sometime might have negative effects on a system (Borgatti et al., 2009). For example, based on their information needs, different stakeholders in PHP have over the past few years developed their own enterprise information systems (EISs). Though the information captured in these systems may have greatly facilitated the operations undertaken by different stakeholders, these heterogeneous systems cannot talk to each other owing to many reasons such as different databases, functions, and operating systems. Another example is the adversarial culture in PHP industry. The stakeholders in housing production may include clients (e.g., private developers and public developers such as Hong Kong Housing Authority), designers, consultants, contractors, suppliers, sub-contractors, end users, and facility managers. Various stakeholders involved in PHP have a hub-and-spoke representation, where the project occupies a central position and has direct connections with the related stakeholders. So the key stakeholders, such as designers and contractors, are not necessarily involved in the whole project lifecycle, witnessing the discontinuity of different parties and different stakeholders that are designated to perform different tasks throughout the main processes of design, manufacturing, storage, transportation, and assembly on site. As such, they are not be able to work together and communicate with each other efficiently and, in fact, can have competing interests. This problem is often referred to as the fragmentation and discontinuity that exists in the supply chain of PHP, which can be further exacerbated by the fact that the whole prefabrication manufacture sector has been moved to offshore areas in the PRD region (new stakeholders, such as the offshore manufacturers, transporters, and host local authorities, are involved, resulting a more complex organization structure) for a reason of lower material and labor cost. With the fragmentation and discontinuity problems, various stakeholder-associated risks, such as low information interoperability between different enterprise resource planning systems, inefficient design data transition and weak response to design change during construction, are nurturing throughout the supply chain of PHP, causing frequent schedule delay that beset the prefabrication industry in Hong Kong.

Under the current design, bid, and build (DBB) used as the typical housing delivery model, the construction of the project has been awarded to the main contractor, and the main contractor will serve as the manager for the overall project, such that every single task of sub-contractor will under the management of the main contractor. As such, main contractors have to guarantee that design information and orders of prefabrication components should be passed from designers to client, to main contractor and finally reach