Understanding stakeholders in off-site manufacturing: A literature review

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Abstract

Off-site manufacturing (OSM) has been attracted much attention in the construction industry. OSM stakeholders are crucial and have a distinguished nature in their management. However, an in-depth understanding of OSM stakeholders and their coordination are still lacking. The paper intends to (a) provide a critical review and analysis of OSM stakeholders based on prior studies, and (b) develop a research framework for their future improvement and practice. The qualitative content analysis was adopted to analyse one hundred and forty-nine journal papers. The results indicated an increased interest of exploring OSM stakeholders' issues since 2007. In addition, the prior studies focused on the two research themes of perceptions and behaviours of stakeholders and stakeholder management. Eleven specific research topics were identified within the two themes, with *Perceived drivers and barriers of OSM adoption* being the most popular one. A research framework was also proposed for systemically articulating the developments and gaps for OSM stakeholders. The research contributes to new insights into an in-depth understanding of OSM stakeholders and their future improvement and practice in the industry.

Keywords: off-site manufacturing; stakeholders; review; framework; qualitative content analysis

Introduction

The construction industry has long been criticized for its poor productivity and sustainability (Fulford and Standing 2014). Initiatives were launched to improve the performance and image of the industry, including off-site manufacturing (OSM) (Taylor 2010). OSM is an innovative construction method where components, elements or modules are produced and assembled in an off-site factory environment before their final on-site installation. Though the take-up of OSM is still limited, the construction industry worldwide shows an increased interest in its adoption due to the benefits it brings (e.g., improved sustainability and productivity) (Hosseini et al. 2018). For instance, in the United Kingdom (UK), the government acknowledged that the adoption of OSM is a tenet of improving the quality and efficiency of its construction sector, and its volume increased by £4 billion during 2004-2006 (Goodier and Gibb 2007). In Australia, the use of OSM was recognized as a key vehicle for driving the development of its property and construction industry over the next decades (Hampson and Brandon 2004).

OSM stakeholders differ fundamentally from those in the conventional in-situ construction projects mainly due to the moving of some traditional on-site activities into an off-site production environment in the OSM practice (O'Connor et al. 2016). Based on the degree of off-site work, OSM covers technologies at different levels such as component and subassembly, non-volumetric pre-assembly, volumetric pre-assembly, and modular construction (Gibb, 1999; Gibb and Isack 2003). To implement OSM smoothly, effectively managing its stakeholders is crucial. Although the well-established methods of stakeholder management in the conventional in-situ construction projects provide valuable insights into the management of OSM stakeholders, their efficiency in the OSM setting is questionable. There is a need of deeply grasping OSM stakeholders and their coordination, thereby constructing a framework which allow managers to more effectively handle their nature. The aim can be achieved through systematically reviewing the historical studies of OSM stakeholders. However, although there are several literature review studies in the OSM filed (Hosseini et al. 2018), a literature review of OSM stakeholders is still lacking. This lack hinders the in-depth understanding of the nature of OSM stakeholders and the suggestions of OSM stakeholder management strategies.

Therefore, the research aims to (a) provide a critical review and analysis of OSM stakeholders based on prior studies, and (b) develop a research framework for their future improvement and practice. This had been achieved by adopting a qualitative content analysis of published journal articles. The research results will not only facilitate an in-depth understanding of the OSM stakeholder issue at the industry, organization, and project levels but also offer valuable insights into the future improvement of OSM stakeholders and their practice.

The Stakeholder Theory

The ‘stakeholder’ concept in the management literature can be traced back to an internal memorandum at the Stanford Research Institute in 1963, where stakeholders were originally defined as ‘those groups without whose support the organization would cease to exist’ (Freeman 1984) and the continued ‘survival’ is the core of the concept. The development of the stakeholder theory then fell into the four groups of corporate planning, systems theory, corporate social responsibility and organizational theory (Elias et al. 2002). In 1984, Freeman’s landmark book Strategic Management: A Stakeholder Approach was published and provided a solid theoretical basis for the stakeholder theory. In this book, Freeman (1984) defined stakeholders as ‘any group or individual who can affect or is affected by the achievement of the organization’s objective’ and constructed a stakeholder management framework in which the three levels of analysis must be consistent, including rational, process, and transactional. Subsequently, the stakeholder theory was advanced and justified from the three perspectives of descriptive (how firms behave), instrumental (how behaviour affects performance), and normative (how firms should behave) (Donaldson and Preston 1995). Further, the recognition of the dynamics of stakeholders contributed to Mitchell et al., (1997)’s stakeholder typology and Rowley (1997)’s network theory of stakeholder influences. More recently, more stakeholder theories were developed and empirical studies were conducted, which is termed as a period of ‘maturity’ by Laplume et al. (2008).

In the project management field, the application of the stakeholder theory is increasing with the acknowledgement that the interests of stakeholders need be dealt with to facilitate project success (Littau et al. 2010). Project stakeholders are defined as 'individuals, groups or organizations who may affect, be affected by, or perceive themselves to be affected by a decision, activity, or outcome of a project' (Project Management Institute 2013). Given the importance of managing multiple project stakeholders and maintaining a balance of their interests, a number of frameworks and models had been developed, covering stakeholder identification and salience, stakeholder analysis, stakeholder participant and engagement (Aaltonen and Kujala 2016). The construction projects are the project type to which the project stakeholder theory was predominantly applied (Littau et al. 2010). In the development of a construction project, various stakeholders with different levels and types of demands and influences are involved, and efficiently evaluating and managing their demands and influences throughout the project life cycle are of great importance (Atkin and Skitmore 2008). The importance of construction stakeholders had resulted in the interest of exploring their management from the perspectives of identification, relationship management, and management framework development (Yang et al. 2009).

OSM Projects and Stakeholders

OSM Projects

OSM is defined as the construction method of manufacturing components, elements or modules in an off-site factory environment away from the project site, and assembling them on-site (Taylor 2010). The benefits of adopting OSM had been well documented, such as minimized on-site operations, less congestion on-site, improved health and safety, increased predictability and efficiency, and added value (CIRIA 1999; Gibb and Isack 2003). However, OSM use is not an antidote to the construction sector. Issues resulted from its adoption were reported, such as more efforts into pre-project planning and difficulties of late design changes (Kamali and Hewage 2016). Consequently, although there is a growing interest of adopting OSM due to its inherent superiority, its uptake is still low (Nadim and Goulding 2011). More efforts (e.g., addressing process, value, supply chain, and knowledge constraints in the use of OSM) are needed to contribute to the transformation from the conventional in-situ construction to OSM (Blismas et al. 2005). Some research works including industry reports have been produced to promote the use of OSM. For instance, Tatum et al (1987) investigated the constructability improvement issue by adopting OSM (e.g., guidelines of OSM use in the early stages of a project). In 2002, Construction Industry Institute (CII) proposed a framework for OSM decision-making, including a decision-timing map, a flow chat, tools for strategic analysis, and suggestions for a more detailed tactical analysis (CII 2002). Moreover, CII also suggested five solution elements to create an optimal environment for OSM use, covering the areas of business case process, execution plan differences, crucial success factors, standardization strategy, and modularization maximization enablers (CII 2013).

OSM projects have unique features compared with the conventional in-situ ones in the design, manufacturing, and construction phases. First, besides the traditional requirements of designing for constructability, OSM projects additionally need design for manufacturing and assembly (Arif et al. 2012). Design technologies and process should be appropriately selected and arranged to facilitate the integration of the design, manufacturing and construction stages and avoid fragmentation (Arashpour et al. 2018). Second, given the customized nature of construction projects, manufacturing technologies and process of OSM should be flexible enough to accommodate design changes and support the implementation of a justifiable level of automation or mechanization (Arif et al. 2012). Third, the very different way of developing an OSM project, where large components and modules are assembled like toy blocks, needs synchronize the construction process with the manufacturing and design processes from early stages (O'Connor et al. 2016). Also, construction technologies should facilitate the effective interaction of the construction process with the manufacturing and design processes and offer deeper insights into decisions (Arif et al. 2012).

OSM Stakeholders

The stakeholder theory indicates that an organization has many relationships with different groups, and considering and balancing their interests to maintain support is important. Thus, it is crucial to identify OSM stakeholders and plan appropriate strategies for their management. Based on the "stakeholder" concepts as defined in Freeman (1984) and Project Management Institute (2013), OSM stakeholders are defined as any individuals, groups or organizations who can affect, be affected by, or perceive themselves to be affected by the achievement of an OSM project's objective (e.g., a decision, activity, or outcome of an OSM project). OSM stakeholders are, but not limited to, manufacturers, suppliers, owners, designers, contractors, clients, governments, and the public, and their identification is project-by-project based (Teng et al. 2017). In practice, their concerns and expectations need be identified, assessed, and satisfied or balanced given their profound impacts on project performance (Olander and Landin 2005).

OSM stakeholders differ from those in the conventional in-situ construction projects due to the differences between OSM projects and conventional ones (O'Connor et al. 2016). In the design stage, OSM requires its architects' roles to be more proactive as experienced coordinators and interdisciplinary engineers through coordinating and balancing different participants' expectations and concerns (Luo et al. 2017), and design professionals should equip themselves with the capability of designing for manufacturability, constructability, and sustainability (Arif et al. 2012). Second, in the manufacturing stage, design and construction personal should adjust their terminologies and processes to liaise with that of manufacturers (O'Connor et al. 2016). Also, the adding of the manufacturing stage means that more parties participate in the development of an OSM project, and it is crucial to ensure that all of them are involved in the project right at the beginning of the design phase (Arif et al. 2012). Importantly, the behaviours and attitudes of manufacturers and suppliers should be paid more attention and their early integration into the OSM supply chain should be ensured (Bildsten 2014; Jeong et al. 2009). Third, construction professionals are usually involved into the development of a traditional project after the design stage, whereas the development of an OSM project requires their integration at early stages to ensure that construction site and approaches are coordinated with other activities (Arif et al. 2012). Also, construction professionals, who are more familiar with the conventional in-situ construction method, should change their mind-sets to be more aware of the benefits of manufacturing so that processes are holistically managed to leverage these benefits (Arif et al. 2012). To manage OSM stakeholders effectively, it is imperative to plan innovative strategies, such as partnerships (Jeong et al.

2009). However, this is not easy as increased coordination among OSM stakeholders is required and the complicated relationships between them lead to the difficulty and complexity of management (Teng et al. 2017).

Research Method

The qualitative content analysis was used in this study. It provides subjective and valid interpretations and inferences from collected data through the systematic classification process of coding and identifying themes or patterns (Elo and Kyngäs 2008). Several reasons contribute to its use in this study. First, the qualitative content analysis concerns meanings, intentions, consequences and context of collected data and revels apparent and latent features of literature, which can reveal the central and natural features of OSM stakeholders. Additionally, it distils both explicit and inferred categories that represent similar meanings, which supports a systematic understanding of the research themes and topics. Moreover, its application procedure is consistent with the mind-set of reviewing literature as both focus on identifying and analysing data, and synthetizing and reporting. Fig. 1 shows the procedure of the qualitative content analysis.

<Insert Fig. 1 here>

Data Collection

Data collection refers to identifying the OSM stakeholder journal articles from mainstream academic databases. Searching in academic databases can ensure the comprehensiveness of search results. The two-step data collection strategy of retrieving and filtering was used (Hu et al. 2016).

Step 1: Retrieving

Determining the academic databases used for article searching. The two mainstream academic databases of Scopus and Web of Science were adopted to search articles. Both platforms are larger and influential abstract and citation databases of peer-reviewed literature, indexing major construction and project management journals (Falagas et al. 2007).

Searching by using keywords. The adopted keyword searching strategy is: *Construction AND ("off-site construction" OR "off-site manufactur*" OR "industriali* building" OR "industriali* housing" OR "modern methods of construction" OR "modular construction" OR "modular building" OR "off-site production" OR "prefabricated building" OR "off-site prefabrication" OR "manufactured construction" OR "manufactured housing" OR "off-site fabrication" OR "precast concrete building" OR prefabrication OR modularisation OR modularization*. Several reasons contribute to its adoption. First, there are various interchangeable terms of OSM, such as modern methods of construction, off-site prefabrication/construction/production, and industrialized building/housing (Pan et al. 2012). Interchangeable terms were used in the search to ensure the comprehensiveness of the search results. Additionally, the term 'construction' was employed instead of a stakeholder-related term. This is given that various stakeholders participate in the development of an OSM project and some have interchangeable terms such as client/developer/owner. Their incorporation into searching will result in the issue of complexity. In contrast, the term 'construction' can not only simplify the searching but also ensure that the search results are narrowed down to the construction field. The keywords were adopted to search in 'Article title, Abstract, Keywords' and 'Topic' in Scopus and Web of Science respectively on August 2, 2017. The searching results were limited to the areas of engineering, economic, technology and management, and only peer-reviewed English journal articles were retrieved. As some interchangeable keywords were not included in this search, a second-round search was conducted on October 18, 2018. In this second round search, eight more keywords/phrases were added into the above suggested search strategy, including *preassembly, prework, prefab, "module assembly", modularity, "modular methods", and "prefabricated prefinished volumetric construction"*. Consequently, more papers can be searched and added to lead to a more comprehensive review work.

Obtaining the preliminary searching results. 1,412 and 434 preliminary articles were retrieved from Scopus and Web of Science respectively in the first round research. In the second round search, 1613 and 507 results were retrieved from Scopus and Web of Science respectively.

Step 2: Filtering

Filtering the preliminary searching results. The filtering rule is that a paper's topic should be closely associated with OSM stakeholders which are defined in the "OSM Stakeholders" section in this study. To ensure the filtering quality, a two-round article selection strategy was employed. The first-round filtering focuses on the review of the 'Article title, Abstract, Keywords' section of an article to select candidate papers, which is followed by the second-round selection of reviewing whole articles to determine the used papers.

Obtaining the final searching results. Finally, 149 articles were obtained and used, and these articles were organized and managed by adopting the Mendeley Desktop.

Data Analysis

The data analysis procedure of the qualitative content analysis includes selecting the unit of analysis, coding and creating categories, and analysing and assessing reliability and validity (Morgan 1993). On the basis, a research framework of OSM stakeholders was proposed.

Step 1: Selecting the unit of content analysis

The unit of analysis is the basis for reporting analyses, and it can be words, sentences, phrases, paragraphs, or whole text (Downe-Wamboldt 1992). The determination of the unit of content analysis is naturally associated with the objective of a study (Downe-Wamboldt 1992). For the purpose of conducting a state-of-the-art literature review, Seuring and Müller (2008) suggested and used a single paper as the unit of analysis. A journal paper is both large and small enough to consider as a whole and analyses as a context for the meaning unit. Consequently, the unit of content analysis is a journal paper in this study.

Step 2: Coding and grouping categories

Coding and grouping categories were conducted through iterative reading and reviewing the used articles to identify significant themes and topics. A codebook was designed and used to record the main contents of articles (including basis article information, research content and research theme and topic), which assists in depicting a comprehensive picture of the prior OSM stakeholder research (Table

1). One of the authors of this paper led the coding and grouping task. The other three authors who are senior researchers in the construction management filed guided and supervised this task. The main reasons of using this strategy is that it can avoid the potential conflicting coding and grouping results resulted from different people's reviewing and coding. In addition, it can also ensure the coding quality based on the senior researchers' guidance and supervision.

<Insert Table 1 here>

Step 3: Analysing and assessing reliability and validity

The article contents were retrieved and transcribed to the codebook, and a database was therefore established by adopting the Microsoft Word 2013 program. The article reviewing process provides the opportunity of re-checking the reliability and validity of the codebook by adjusting codes. Additionally, the process was guided and supervised by senior researchers. All lead to the refinement of the codebook to improve its reliability and validity, which ensures the quality of the data analysis results.

Step 4: Developing a research framework

Based on the overview of the prior research and the critical review of the features of OSM projects, a research framework which revealed the current OSM stakeholder research topics and offered valuable future insights at the three levels of industry, organization and project was developed for OSM stakeholders' future development and improvement.

Overview of Research on OSM Stakeholders

Distribution of the Articles

The one hundred and forty-nine articles are distributed in 52 journals. The main sources of these articles are *Construction Management and Economics* (17), *Journal of Construction Engineering and Management* (13), *Journal of Cleaner Production* (9), *Journal of Architectural Engineering* (7), and *Architectural Engineering and Design Management* (7). All these journals are leading ones in the field of construction engineering and management (Wing 1997).

Publications in Years

Fig. 2 depicts the number of publications over time. The average annual publication number before 2007 was less than 2 but has increased since 2007. A Mann-Whitney U test was conducted by adopting the IBM SPSS Statistics 23 program to examine whether the increase is significant or not. The Mann-Whitney U test was used as it is a non-parametric test adopted for testing whether two samples come from the same population and it does not require the assumption of normality (Rosner and Grove 1999), which is suitable for testing differences between the two "publication number" groups in the study. The results indicated that the number of the OSM stakeholder research has increased significantly since 2007 (u=-4.877, Sig.=0.000).

<Insert Fig. 2 here>

Research Themes and Topics

The prior OSM stakeholder studies covered the two themes of stakeholders' perceptions and behaviours, and stakeholder management (Table 2). Most studies focused on exploring OSM stakeholders' perceptions and behaviours, whereas the stakeholder management research has been largely under-researched. In addition, eleven specific research topics were identified, with the most popular one being *Perceived drivers and barriers of OSM adoption*. Regarding the stakeholder management research, the mostly explored topic is *Stakeholders' integration, collaboration and relationships*.

<Insert Table 2 here>

Overview of the OSM Stakeholder Research

Stakeholders' Perceptions and Behaviours

Perceived Drivers and Barriers of OSM Adoption

Many stakeholders hold a positive attitude towards OSM adoption, with the predicted increasing take-up of OSM (Goodier and Gibb 2007; Larsson et al. 2014; Lu and Liska 2008; Pan et al. 2007, 2008). The stakeholder theory indicates that stakeholders' perceptions impact their corresponding behaviours, and a positive perception tends to result in a positive result (Olander and Landin 2005). Consequently, it is reasonable to state that there can be seen an increase of the future OSM up-take in practice given the identified positive attitudes of OSM stakeholders to OSM use. Larger organizations are generally more favourable to OSM use due to their superiority in the overall project delivery and construction methods (Hanna et al. 2017; Pan et al. 2007; Rahman 2014). Stakeholders from industrialized countries tend to believe that industry practitioners contribute more to the take-up of OSM (Goodier and Gibb 2007; Said 2016), whereas those in developing economics state that governments play more crucial roles in the process (Zhai et al. 2014).

Twenty-three studies explored the drivers of OSM adoption based on stakeholders' perceptions, and eight specific drivers were identified (Table 3). The mostly perceived one is Time benefits (e.g., shorten duration), which is followed by Quality benefits (e.g., high product quality) and Cost benefits (e.g., reduced cost). The result mirrors the importance of the conventional project management objectives of cost, time and quality in the decision process of using OSM (Gao et al. 2018). In addition, the environmental sustainability benefits (e.g., waste reduction) are becoming a key facilitator (Jaillon and Poon 2008, 2014). A further examination found that OSM stakeholders' background (e.g., economics, country, affiliation, and historical experience) impacts their perceptions of drivers (Goodier and Gibb 2007; Jaillon and Poon 2010; Lu and Liska 2008; Steinhardt and Manley 2016). However, the ranks of these barriers do not show any specific patterns. As shown in Table 3, stakeholders in both developing and developed economics view the benefits of time, cost and quality as top drivers. In addition, compared with stakeholders in developing economics who focus more on Environmental sustainability benefits, stakeholders in developed economics value more on Risk, health and safety, and Process and program advantages.

<Insert Table 3 here>

However, the benefits of OSM adoption have not been fully understood by stakeholders, leading to their prudent attitude towards OSM and a slow take-up in practice (Choi et al. 2018; Gan et al. 2018a; Gan et al. 2018b; Jiang et al. 2018; Han and Wang 2018; Hwang et al. 2018a; Gibb and Isack

2003; Goodier and Gibb 2007; Kamar et al. 2014; Kempton 2010; Kempton and Syms 2009; Nadim and Goulding 2011; Pan et al. 2008; Sadafi et al. 2011; Said 2016; Zhai et al. 2014). Eight kinds of barriers were retrieved from prior thirty-one studies (Table 4), with the top-ranked ones being Cost (e.g., high investment), Progress and programme (e.g., late design change difficulties) and Knowledge, experience and skill (e.g., experience lacking). OSM stakeholders' background (e.g., economics, country, affiliation, nature of job, and organization size) again impacts their perceptions of barriers (Rahman 2014). As shown in Table 4, the stakeholders in the developing economics viewed Knowledge and experience as the most important barrier, whereas it was not identified as important as that in the developed countries. In addition, compared with stakeholders in developing economics, these stakeholders in developed countries viewed the issues related to Cost (e.g., high overall cost) and Progress and programme (e.g., inflexible for late changes) were two more important barriers of OSM use. To mitigate these barriers, the prior studies revealed that OSM stakeholders can play important roles, such as government's roles in formulating policies and regulations and industry practitioners' roles in establishing proper understanding and knowledge of OSM (Hedgren and Stehn 2014; Luo et al. 2015).

<Insert Table 4 here>

Stakeholders' Best Practices and Practical Strategies

The previous studies reported stakeholders' best practices of OSM implementation in some countries or regions, such as the precast structural elements and volumetric precast modular units in Hong Kong (Jaillon and Poon 2009; Pan et al. 2012; Said 2015; Tam et al. 2015). The prior studies also identified various practical issues with which OSM stakeholders were encountered in terms of subcontracting (Hsieh 1997), enterprise resource planning (Bergström and Stehn 2005), design innovation (Onyeizu and Bakar 2011), cost planning and payment (Dzulkalnine et al. 2016; Shamsuddina et al. 2015), maintenance management (Ismail et al. 2016), production lead-time in supply chain management (Zhai et al. 2017), and use of Building Information Modelling (BIM) (Mostafa et al. 2018). As the adoption of OSM is a complex and multi-layered structure of business management, it is crucial for OSM stakeholders to build practical strategies for their best practices (Pan et al. 2012). Some of the reported practical strategies and best practices include supply chain strategy (Jeong et al. 2009; Kamar et al. 2012; Pan et al. 2012; Zhai et al. 2017), production elements forecasting (Dawood and Neale 1993; Sing et al. 2014), lean production (Low and Choong 2001b, 2001a; Meiling et al. 2012; Nahmens and Ikuma 2009; Nahmens et al. 2012), BIM use (Mostafa et al. 2018a), customization (Nahmens and Bindroo 2011; Wikberg et al. 2014), risk management (Hassim et al. 2009; Kim et al. 2012; Li et al. 2013; Shaari et al. 2016), standardization (O'Connor et al. 2015), and leagile strategies (Mostafa et al. 2018b). For instance, Mostafa et al. (2018b) suggested using leagile strategies to optimize the delivery of OSM projects and a multi-criteria decision-making model were proposed to facilitate decision-makers' selection of specific strategies. The use of best practices and practical strategies is of great importance to stakeholders in practice. Especially, according to the stakeholder theory, they are one of the sources of stakeholders' competitive advantages to improve their performance for survival (Laplume et al. 2008). However, in the implementation of these strategies, OSM stakeholders need overcome problems such as poor stock management (Wu and Low 2014), conventional production culture and site-based mentality (Höök and Stehn 2008), negative impacts of non-value activities (Senaratne and Ekanayake 2012; Wu and Feng 2014), financial difficulties, demand uncertainties, site congestion, confidence lacking (Low and Choong 2001b, 2001a; Oral et al. 2003), difficulties of transforming customers' needs into design parameters, and conflicts between customization and efficiency (Nahmens and Bindroo 2011).

Perceived Performance of OSM Adoption and Customer Satisfaction

The benefits of the OSM construction method lead industry stakeholders believe that its use can improve project performance, which was confirmed by practical experience (e.g., improved productivity and sustainability) (Badir et al. 2002; Hanna et al. 2017; Jaillon and Poon 2008; Jeong et al. 2009). However, some performance limitations (e.g., high cost, pollution, and labour reduction) were also reported (Jaillon and Poon 2008). For instance, Jaillon and Poon (2008) found that OSM use might increase the unemployment rate in the construction industry due to the reduction of labour requirement on-site. OSM stakeholders also perceived a set of factors that can impact the performance of OSM projects, with the important ones being time, safety, buildability, and employee empowerment (Alazzaz and Whyte 2015; Yunus and Yang 2014). For example, Alazzaz and Whyte (2015) revealed that employee empowerment can help increase the performance of OSM projects through positively impacting fabrication-yard productivity levels.

Quality is a key consideration when stakeholders determine their construction method. Practical evidence retrieved from Malaysia demonstrates that the quality of OSM-constructed buildings is better than those constructed by traditional construction methods, which encourages stakeholders' future OSM use (Ali et al. 2012). Despite so, quality problems can also be resulted from various factors during the design, production and construction stages. For instance, the factors identified by Chinese construction professionals include inaccurate design of the connecting points between core components, lacking design and production norms and standards, lacking quality criteria, lacking quality management system, and lacking construction technical guidelines (Gan et al. 2017). Cost performance of OSM projects is impacted by factors such as "specification and standards for prefabricated building design", "related experience of manager", and "rationality of precast component split" (Xue et al. 2017). For instance, the lack of specification and standards can result in issues (e.g., mismatching of precast components) which further impact the cost performance of OSM projects profoundly. Many stakeholders estimated that OSM construction is about 20% more expensive than conventional construction (Jaillon and Poon 2008). To optimize cost performance, (Xue et al. 2018a) suggested the strategy of collaboration management given that cost management is not a simple linear combination.

OSM stakeholders are showing increased interests in the sustainability performance of OSM projects, with the perceived influencing factors being waste generation and disposal, and material consumption (Yunus and Yang 2014). OSM stakeholders valued all the three sustainability categories of social, environmental, and economic (Kamali and Hewage 2017; Švajlenka and Kozlovská 2018a). Kamali et al. (2018) developed a life cycle sustainability performance assessment framework for OSM projects. In this framework, suitable sustainability performance indicators under the three sustainability dimensions were included, and the weights of indicators were assigned by using the Analytic Hierarchy Process. For instance, the top-ranked indicators in the social sustainability dimension include workforce health and safety, safety and security of building, and affordability (Kamali et al. 2018). It should be noted that stakeholders are also concerned about the poor sustainability of OSM projects. For instance, some stakeholders believed that the pollution resulted from transportation of prefabricated components is a major environmental limitation of OSM (Jaillon and Poon 2008).

Customer satisfaction is positively associated with the performance of OSM products (McGrath and Horton 2011; Nahmens and Bindroo 2011). Although housing produced by adopting OSM has the capability of satisfying customers' needs (Phillips et al. 2016), dissatisfactions were also reported. For instance, based on a post-occupancy evaluation, McGrath and Horton (2011) reported the intrusive noise issue in an OSM-constructed student accommodation in UK. To improve customer satisfaction in the OSM market, Azam Haron et al. (2015) developed a quality function deployment model based on the 'quality' matrix, 'function' matrix and a combination of 'quality' matrix and 'function' matrix. In addition, strategies were suggested to improve customer satisfaction, including policies improvement, government supervision, improvement of building design, standards provision, and quality control (Azam Haron et al. 2015).

Stakeholders' Selection Criteria of OSM as a Construction Method

Stakeholders' decision-making process is usually complicated due to the technical, organizational, and environmental complexity of projects (Altonen and Kujala 2016). However, it seems that stakeholders tend to simplify the decision-making process in the selection of OSM as a construction method. Industry evidence indicates that stakeholders' decision of OSM use largely relies on their historical experience or the cost-related performance (Chen et al. 2010; Park et al. 2011; Steinhardt and Manley 2016). For instance, Steinhardt and Manley (2016) revealed that the builders' determination relies on their attitudes, beliefs, and autonomy. However, this leads to poor implementation or project failure as the decision-making process is complicated with the need of assessing various factors such as industry-related and firm-related ones (Zakaria et al. 2018; Azhar et al. 2013; Gibb and Neale 1997; Noorzai et al. 2017;

Said 2016). And, the importance of these factors is project-based, relying on project features and experts' judgement (Azhar et al. 2013). Zakaria et al. (2018) identified 14 factors that impact the decision to use OSM in the Malaysian construction sector, covering the structural, contextual and behavioural themes. Song et al. (2005) developed a decision framework to ensure a thorough assessment of the influential factors (e.g., schedule, cost, labour, safety, site attributes, etc.) that are related to OSM decisions. In addition, there are also some other developed approaches to facilitate the decision-making process of OSM use such as the feasibility prediction approach (Said 2016), the knowledge-based approach (Murtaza et al. 1993), and the Knowledge-Based Decision Support System for Prefabricated Prefinished Volumetric Construction (Hwang et al. 2018b). Due to the increased concern of sustainability, Chen et al. (2010) depicted the sustainability selection criterion of OSM use, covering the social, economic, and environmental dimensions. It is also important to determine the level of modularization. To achieve this, Sharafi et al. (2018) developed a multi-criteria decision analysis model, including quality and safety, productivity and efficiency, cost and sustainability, and constructability and design.

Stakeholders' Business Models and Competitive Advantages

The business model innovation of OSM stakeholders is promoted by favourable business environment and entrepreneurial cognition (Liu et al. 2017), where a business environment can be assessed by using the SWOT analysis (Li et al. 2016; Mohamad et al. 2012; Yunus and Yang 2014; Jiang et al. 2018). In practice, OSM stakeholders require new business models, which involves change management, new relationships, skills, technology, process and working ways, as the way in which professionals interact with each other (Goulding et al. 2015). Case studies of OSM companies in Sweden and North America indicated that a good fit and balance between the offering, operational platform and market position of a business model are of great importance to the success of companies (Lessing and Brege 2018). Brege et al. (2014) suggested the approach of proposing new business models by adapting a general business model, and its feasibility was confirmed by the Swedish manufacturers.

The use of OSM enhances contractors' competition capabilities through positively influencing their projects' design, constructability, sustainability, and innovation (Chan et al. 2004). However, OSM itself is not a sustainable source of contractors' competitive advantages (Chiang et al. 2008). Instead, contractors should focus on the innovation of the OSM process such as improving the efficiency of their supply chain management (Chiang et al. 2008). In practice, contractors had adopted various business strategies to attain competitive advantages such as close supply chain loop, investment planning of manufacturing factory, huge volume and repetitive design, and being a total solution provider (Kamar et al. 2012).

Perceived Critical Success Factors of OSM Implementation

Critical success factors (CSFs) of influencing OSM implementation were explored based on stakeholders' judgement in some countries/regions (Gibb and Isack 2003; Kamar et al. 2014; Larsson et al. 2014; Li et al. 2018; O'Connor et al. 2014; Ojoko et al. 2018). For instance, O'Connor et al. (2014) identified twenty-one CSFs in the US, with the top-ranked ones being module envelope limitations, team alignment on drivers, adequate owner planning resources and process, timely scoping and design freeze, and due recognition of possible early completion from modularization. Choi et al. (2016) pointed out the CSFs for cost and schedule success of OSM projects, including timely design freeze, owner-furnished/long-lead equipment specification, vendor involvement, and management of execution risks. Li et al. (2018) identified the CSFs that impact OSM project planning and control, including Technology and method, Information, communication and collaboration, External environment, Experience and knowledge, and Project manager's competence.

Stakeholders' Readiness to OSM Implementation

The adoption of OSM creates a new project environment that demands its stakeholders' readiness to change. In Australia, though OSM practitioners were well aware of the need to change and had undertook some practice changes (e.g., revising policies and performance management systems), these changes mainly focused on planned approaches and their emergent organizational change strategies were underdeveloped (Wong et al. 2017). The situation was worse in some countries due to the reported un-readiness of their stakeholders (e.g., the contractors and architects in the Malaysian private project sector) (Nawi et al. 2015), which were resulted from experience lacking, poor communication, financial problems, and restrictions from stakeholders (Hanafia et al. 2016; Tamrin et al. 2016). To improve the situation, suggestions were proposed in terms of training, government incentives, design freeze, awareness improvement, and standardization (Tamrin et al. 2016).

Stakeholders' Training and Education

OSM stakeholders had acknowledged the benefits of OSM training and education (e.g., alleviating the skill shortage), and planned to invest more effort in developing training and education programs (Hanna et al. 2017; Nadim and Goulding 2009). However, the traditional training and education methods have many limitations and were criticized for being costly, limited and high demand for the actual training environment. Thus, Goulding et al. (2012) developed a virtual reality interactive training environment prototype, which provides a risk-free environment for learning and experiencing. Experience from UK indicates that building collaborations between universities and industry is an effective approach of improving skills and development application in the workplace such as developing skills training content to meet the requirements of the OSM industry (Hairstans and Smith 2018).

Stakeholder Management

Stakeholders' Integration, Collaboration and Relationships

There is a need of integrating OSM stakeholders in supply chain to facilitate OSM use (Doran and Giannakis 2011). This is easy to understand from the perspective of the stakeholder theory. Stakeholder integration can facilitate the address of complicated issues through pooling resources, capitalizing on complementary capabilities, achieving economics of scales, and enhancing innovation (Savage et al. 2010). However, this is not easy in practice as the integration is complicated and impacted by human, process, and technologies (Nasrun et al. 2016; Nawi et al. 2011). The collaboration between OSM stakeholders is a consensus due to its benefits. For instance, Xue et al. (2018b) stated that stakeholder collaborative management (interaction frequency, emotional intensity, familiarity, and reciprocity) has a positive influence on OSM projects' cost performance. Nevertheless, the lack of shared understanding of the preferred means for collaboration between stakeholders was a significant barrier of collaboration

(Nadim and Goulding 2009). London and Pablo (2017) developed an expanded theoretical and empirical conceptualization of collaboration for OSM projects on the basis of the actor-network theory, which deepens the understanding of the stakeholder collaboration issue in the OSM market.

Qualified stakeholder relationships are the basis of project success. For a specific stakeholder, it is crucial to develop appropriate relationships with other parties by eliminating separations between them, which helps develop alliance to make good use of individual advantages and exchange resources (Aaltonen and Kujala 2016). In the OSM research field, Said (2015) reported that effective partnerships had been built through streamlining business and project operations in the US electrical construction sector. Teng et al. (2017) identified two specific OSM stakeholder relationships, including positive symbiosis (e.g., owners and designers) and commensalism (owners and users) in China. Prior studies also explored relationships between two specific OSM project parties, including the buyer-supplier relationship (Bildsten 2014), the contractor-subcontractor relationship (Hsieh 1997), the contractor-supplier relationship (Hofman et al. 2009), and the manufacturer-retailer relationship (Jeong et al. 2009). For instance, the previous studies revealed that the standardized items require a long-term and loose buyer-supplier relationship, whereas a close and long-term relationship is appropriate for the specialized solutions and services (Bildsten 2014; Bildsten et al. 2011). In practice, issues about OSM stakeholder relationships were reported. For instance, the level of general Chinese contractors' supplier relationship management is low, and there is a lack of inter-organization integration between suppliers and contractors (Liu et al. 2018).

Stakeholder Identification, Roles and Attributes

Stakeholder identification is the first step of stakeholder analysis. Teng et al. (2017) identified a variety of stakeholders in the development of an OSM project in China based on experts' judgement, including developers, suppliers, contractors, designer, users, and capital provider. One of the key issues in the identification process is that the identified stakeholders should be comprehensive. Besides, stakeholder identification should consider the dynamism issue as different stakeholders participant in different project stages. Among these stakeholders, Luo et al. (2017) suggested that architects' roles should be changed from an 'architectural work' mode to a 'building product' mode as coordinators and interdisciplinary engineers to balance the demands and requirements of different parties. Gan et al. (2018a) indicated that the government and developers hold a central position in the stakeholder network of an OSM project, indicating their great impacts on OSM project implementation. Jeong et al. (2006) explored the characteristics and purchasing process of customers, and the organizational characteristics, information and capital flow of retailers and manufacturers, which benefits their management. Client order information is of great importance in managing the OSM system. Mostafa and Chileshe (2018) developed a discrete-event simulation model by using Arena simulation software to study the impacts of client order interaction on performance of OSM supply chain in the Australian context.

Stakeholders' Requirements and Expectations

Understanding stakeholders' requirements and expectations is a key task of stakeholder analysis. Prior studies reported OSM customers' expectations and requirements in several countries/regions (Armacost et al. 1994; Phillips et al. 2016; Viking and Lidelöw 2015; Švajlenka and Kozlovská 2018b). For instance, Armacost et al. (1994) revealed that the customers' needs referred to the style, process technology, materials, performance feature and functionality in the US manufactured housing market. The stakeholder theory indicates that there is a possibility that different stakeholders have conflicting expectations and concerns. It is therefore important to identify these conflicts and propose appropriate management strategies.

A Research Framework for OSM Stakeholders

OSM stakeholders are under-researched compared with those in the conventional in-situ projects, with only a few topics being insufficiently explored. In addition, the OSM stakeholder studies are scattered, which lacks an exhaustive grasp. There is a need of systemically studying the OSM stakeholder issue, which can be assisted by developing a research framework. The term 'stakeholder' should breakthrough its original meaning that was defined by Freeman (1984) to cover a wider scope due to the multiple roles that OSM stakeholders play in the OSM practice such as industry practitioners, firms, and project participants. OSM stakeholders work as industry practitioners at the industry level and can influence the industry development profoundly. As construction organizations, they adopt appropriate strategies for survival in a competitive environment. At the project level, they are project participants who should be well managed. In this respect, the OSM stakeholder issue can be systematically explored by using the top-down typology at the industry, organization, and project levels (Fig. 3). It provides an analytical framework to grasp the nature of OSM stakeholders and offers key insights for their improvement. Clearly, the research at the industry and organization levels views stakeholders as players of practical activities, whereas they themselves are the research objective at the project level. The three levels are interacted. For instance, an OSM stakeholder with core competence and competitive advantages is more likely to be the benchmark of the industry and has more power to impact the process of project implementation. A further examination of the research topics in Table 2 indicated that these topics can be classified into these three levels. Specifically, the perceived drivers and barriers of OSM use and the readiness to OSM adoption were explored from the perspective of industry. The topics of stakeholder management are linked to the project level. Others were studied at the organization level.

<Insert Fig. 3 here>

Industry Level: OSM Stakeholders as Industry Practitioners

At the industry level, the prior studies focused on the truth that the OSM sector is in its initial stages, revealing stakeholders' understandings of the barriers and drivers of the OSM industry development and their readiness to OSM use (Fig. 3). Future studies can further investigate the interaction of these identified barriers and drivers, and their impacts on the OSM sector development by methods such as system dynamics. Courses of action by which OSM stakeholders can be more-prepared to OSM use should also be explored.

The development of the OSM industry needs overcome various barriers including those that are related to OSM stakeholders. Specially, in the developing economics, the prior studies offer the insight of enhancing industry practitioners' experience and knowledge. Abundant experience and knowledge of practitioners are a CSF of implementing OSM (O'Connor et al. 2014). Nevertheless, the review revealed that a major barrier to OSM use in the developing economics is their players' insufficient experience and knowledge (Jaillon and Poon 2010; Mao et al. 2015; Sadafi et al. 2011). As part of relieving the issue, delivering training and education programs, and learning from other countries are two strategies. In the developed economics, the situation changes. More efforts should focus on changing the industry players' negative perceptions of OSM and improving their motivations for OSM use. The negative image of OSM products, grounded in the historical failure of off-site practises rather than technical barriers, has been rooted in the mind-set of the industry players, which leads to their resistance to OSM use (Goodier and Gibb 2007; Steinhardt and Manley 2016). Some of the strategies of improving this situation are applying both hard and soft technologies, demonstrating performance of OSM products, and delivering sites with practical OSM examples.

Governments play foundational roles in the industry development by formulating policies. Though the OSM sector has developed for a long period, as revealed in many studies from both the developing and developed economics that poor policies are still an issue of hindering the development of the sector (e.g., Larsson et al. 2014; Mao et al. 2015). Therefore, there is a need of revisiting and reviewing governments' policies to propose proper ones as a new starting-point of positively intervening the sector development. Especially, the policies should play roles of coordinating different elements of the industry development (e.g., innovation, technology, resource, employment) in the different stages (e.g., manufacturing, transportation, construction, and maintenance) to build an efficient policy environment. This will be a crucial component of a supportive OSM implementation environment that relieves barriers and makes stakeholders more-prepared.

Organization Level: OSM Stakeholders as Organizations for Survival

At the organization level, the previous studies can be grouped into the three dimensions of decision-making, process, and outcome (Fig. 3). The majority of these studies were explored at merely one of these dimensions. Nevertheless, these three dimensions are inter-related in nature as decision-making influences outcomes indirectly by directly impacting process parameters. Thus, the future studies can investigate the interaction and integration of these three dimensions to facilitate an in-depth understanding of the OSM stakeholder issue at the organization level.

As many parties participate in the development of an OSM project, a collaborative environment to efficiently coordinate their interests is a consensus (Hofman et al. 2009). However, this has been largely hindered by adopting the conventional procurement systems (CPSs) given incompatibility issues (Pan et al. 2007). First, there is a potential conflict between the magnified importance of the off-site production stage in the OSM process and the relative ignorance of this stage in the CPSs. In addition, compared with the conventional in-situ projects, the responsibilities and authorities of parties in the OSM practice are changed and the determination of their responsibilities and authorities are more complicated. This brings the challenge of assigning the right responsibilities and authorities to OSM players in an optimal way when the CPSs are adopted. Moreover, the implementation of OSM demands that OSM parties build more collaborative and integrated relationships, which can be hardly achieved by using the CPSs. Consequently, improving procurement (Pan et al. 2007) or exploring alternative forms of procurement (Blismas and Wakefield 2009) are necessary. Collaboration has been identified as a facilitator of the OSM process, as an assistance to behavioural change of problem-addressing, and as a crucial component of the OSM practitioners' relationships (London and Pablo 2017). All these offer the insight of incorporating the 'collaboration' philosophy into the OSM procurement process to develop a collaborative procurement system for OSM projects. Based on the review of historical studies, some of the key issues that should be concerned in the design of this collaborative procurement system are: (1) the early integration of OSM parties (especially manufacturers, designers, and contractors), and their coordination and collaboration; (2) the right assignment of responsibilities and authorities to OSM parties; (3) the control of the off-site production stage, and its integration with on-site stages; (4) the proactive roles of OSM parties; (5) the effective flow of information and resources between OSM parties during the life cycle of an OSM project; (6) the effective communication cross interfaces, trust, and commitment.

Project Level: OSM Stakeholders as Project Participants Being Managed

At the project level, the OSM stakeholder issue is under-researched with merely few topics being explored. The future studies can follow the stakeholder management procedure suggested by Project

Management Institute (2013) to comprehensively grasp the OSM stakeholder management issue, which includes stakeholder identification, stakeholder management planning, stakeholder engagement management, and stakeholder engagement control.

Manufacturers are a crucial but special stakeholder in the OSM practice compared with those in the conventional in-situ construction projects, which is mainly resulted from the magnified importance of the off-site production activities. Their responsibilities and authorities differ from these that they have in the traditional projects. Therefore, there is a need of revisiting and reviewing the roles that manufacturers paly in the OSM practice. A preliminary thinking, based on the historical studies, gives the insight that they should play at least three roles during the life cycle of an OSM project, including decision-supporters, producers, and coordinators. First, manufacturers ought to be early integrated into the OSM practice as decision-supporters to offer suggestions and advices on the decisions of owners and designers. Additionally, manufacturers are located at the central place of the off-site production stage to be worked as producers. Moreover, manufacturers should be worked as coordinators to connect off-site activities with on-site ones so as to facilitate the implementation of other OSM stakeholders' work. They should also be decision-supporters at the facility operation and maintenance stages. The uniqueness and importance of manufacturers require project managers to propose proper management strategies so as to well response to their roles. For instance, managers' management strategies are suggested to facilitate, support, and assist their roles of decision-supporters, producers, and coordinators respectively.

Discussions and Contributions

The under-researched conclusion of this study is consistent with the review results of Hosseini et al. (2018) and Li et al. (2014) that the stakeholder issue is not identified as a main OSM research area. In fact, the prior OSM studies focused more on the 'hard' aspects of OSM (e.g., concrete and production planning), whereas strategic aspects, such as stakeholder management, were not positioned as central areas (Hosseini et al. 2018). This gap hinders the understanding of OSM stakeholders, which will ultimately harm the development of the OSM sector (O'Connor et al. 2016). The future studies can follow the suggested directions as discussed at the three levels of industry, organization, and project in the above section.

The proposed research framework breakthroughs the traditional perception which primarily restricts the 'stakeholder' concept to the project level (Aaltonen and Kujala 2016) by incorporating thinking at the industry and organization levels. In fact, the stakeholder issue is also closely associated with industry and organization development in nature as evidenced widely from the strategic management literature (Chinowsky and Meredith 2000; Fox and Skitmore 2007). Exploring at the three levels deepens understandings of OSM stakeholders in a comprehensive way, which is valuable especially given that the OSM sector is in the initial stages. The insights provided at the three levels are conceptual, which requires further efforts to detail, test and validate.

Apart from the review and analysis of stakeholders in the OSM practice, the main theoretical contribution of this study is that the proposed research framework, based on the top-down typology of project, organization and industry, extends the default and changeless range of the project stakeholder issue. It represents an advancement in the project management literature through systemically grasping the stakeholder issue from the perspectives of both macro and microscopic. Regarding the practical contributions, the study facilitates industry practitioners' grasp of the nature of OSM stakeholders based on the summarized historical literature. In addition, the insights offer practical suggestions on the future development and improvement of OSM practitioners. All these will support the development of the OSM industry and firms, and the management of OSM stakeholders.

Conclusions

Stakeholders serve as a key component to the success of projects, and their perceptions and behaviours impact project performance profoundly. This study offers a critical review of the historical OSM stakeholder studies based on the qualitative content analysis of selected journal papers. The research results revealed eleven research topics of OSM stakeholders within the two research streams of stakeholder perceptions and behaviours and stakeholder management. The research also developed a research framework based on the top-down typology of the three levels of industry, organization and project, which would benefit the understanding of the OSM stakeholder issue.

Based on the above discussions, a variety of research gaps can be identified. First, at the industry level, an understanding about the interactions between stakeholder perceived factors impacting industry development is still not clear and how these factors can impact stakeholders' readiness to adopt OSM is also under-researched. Future studies can address this research gap by using methods such as system dynamic. System dynamics is suggested as it can model large-scale socio-economic systems and focuses on understanding how the physical processes, information flows and managerial policies interact so as to create the dynamics of the variables of interest, which can be used to measure the interplay of different components and their impacts in a given system (Vlachos et al. 2007). Second, at the organization level, prior studies have ignored the interactions between stakeholders' decision-making, process and outcomes as they merely focused on one specific dimension. Future studies at the organization level should integrate these three dimensions together to facilitate a comprehensive understanding of OSM stakeholders' competition and survival as organizations. Third, at the project level, there is a lack of explorations of OSM stakeholder management. Future studies can focus on the key issues in the stakeholder management field such as OSM stakeholders' identification, stakeholder management planning, stakeholder engagement management, and stakeholder engagement control. Furthermore, the developed framework was discussed from the perspective of the three levels. It is also meaningful to discuss OSM stakeholders from the perspective of a project life cycle. For instance, future studies can classify OSM stakeholders into different project stages and discuss their power and interest to visualise and map stakeholder influence. At last, some key insights were proposed to facilitate the future development and improvement of OSM stakeholders. Future studies can work in these areas such as how to promote stakeholders' learning and role changing in the industry level, how to ensure that governments enact suitable policies to facilitate OSM use, how to develop collaborative procurement system to integrate stakeholders, and how to defined manufacturers' roles in OSM projects.

The study has several limitations. It merely focuses on journal papers, and lacks the review of conference papers, reports and on-line materials which may also provide additional implications for understanding the OSM stakeholder issue. In addition, as the research findings of prior studies are commonly fragmented, it is rather difficult to cover every detail of prior studies. These limitations should be rectified in future studies. Though these limitations, this research contributes to a better understanding of the stakeholder issue in the OSM practice.

Data Availability Statements

Data generated or analyzed during the study are available from the corresponding author by request.

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