State-of-the-Art Review

Understanding Stakeholders in Off-Site Manufacturing: A Literature Review

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Abstract: Off-site manufacturing (OSM) has attracted much attention in the construction industry. OSM stakeholders are crucial in its implementation and are distinct in regard to their management. However, an in-depth understanding of OSM stakeholders and their coordination is still lacking. The paper intends to (1) provide a critical review and analysis of OSM stakeholders based on prior studies, and (2) develop a research framework for their future practice and improvement. A qualitative content analysis was adopted to analyze 149 journal papers. The results indicated an increased interest in exploring OSM stakeholders' issues since 2007. In addition, prior studies focused on the two research themes of stakeholder perceptions and behaviors and stakeholder management. Eleven specific research topics were identified within the two themes, with perceived drivers of and barriers to OSM adoption being the most popular. A research framework was also proposed for systemically articulating developments and gaps for OSM stakeholders. The research contributes to an in-depth understanding of OSM stakeholders and their future practice and improvement in the industry. **DOI:** 10.1061/(ASCE)CO.1943-7862.0001674.

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Introduction

The construction industry has long been criticized for its poor productivity and sustainability (Fulford and Standing 2014). Initiatives have been launched to improve both the performance and the 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 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 in the early 2000s, the government acknowledged the adoption of OSM to be a tenet of improving the quality and efficiency of the UK construction sector, and as a result OSM 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 the Australian property and construction industry over the next decades (Hampson and Brandon 2004).

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

This research aims to (1) provide a critical review and analysis of OSM stakeholders based on prior studies and (2) develop a research framework for future improvement of their practice. This has been achieved by a qualitative content analysis of published journal articles. The research results will not only facilitate an in-depth understanding of OSM stakeholders at the industry, organization, and project levels but will also offer valuable insights into the future improvement of OSM stakeholder practice.

Stakeholder Theory

The stakeholder concept in management literature can be traced 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, p. 1); continued survival is the core of the concept.

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The development of stakeholder theory then fell into four groups: corporate planning, systems, corporate social responsibility, and organization (Elias et al. 2002). In 1984, the landmark *Strategic Management: A Stakeholder Approach* was published and provided a solid theoretical basis for stakeholder theory. In this book, Freeman (1984, p. 46) 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—rational, process, and transactional—must be consistent Subsequently, stakeholder theory was advanced and justified from three perspectives—descriptive (how firms behave), instrumental (how behavior affects performance), and normative (how firms should behave) (Donaldson and Preston 1995). Further, recognition of the dynamics of stakeholders contributed to Mitchell et al.'s (1997) stakeholder typology and Rowley's (1997) network theory of stakeholder influences. More recently, in what is termed a period of maturity by Laplume et al. (2008), additional stakeholder theories were developed and empirical studies were conducted.

In the project management field, application of the stakeholder theory is increasing with the acknowledgment 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, p. 563). 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 identification and salience, analysis, and participants and engagement (Aaltonen and Kujala 2016). Construction is the project type to which the stakeholder theory has been 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 these demands and influences throughout the project life cycle is of great importance (Atkin and Skitmore 2008). The importance of construction project stakeholders has raised interest in exploring their management from the perspectives of identification, relationship management, and management framework development (Yang et al. 2009).

OSM Projects and Stakeholders

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 have 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 is not an antidote. Issues resulting from its adoption have been reported, such as more effort in preproject planning and difficulties with late design changes (Kamali and Hewage 2016). Consequently, although there is a growing interest 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) are needed to contribute to the transformation from conventional in situ construction to OSM (Blismas et al. 2005).

Some research, including industry reports, has been produced to promote the use of OSM. For instance, Tatum et al. (1987) investigated constructability improvement with OSM (e.g., OSM guidelines in the early stages of a project). In 2002, the Construction Industry Institute (CII) proposed a framework for OSM decision making, including decision-timing maps, flowcharts, strategic analysis tools, and more detailed tactical analysis (CII 2002). CII also suggested five solution elements to create an optimal environment for OSM use, covering business case processes, execution plan differences, crucial success factors, standardization strategy, and modularization maximization enablers (CII 2013).

OSM projects have unique features compared with conventional in situ projects in the design, manufacturing, and construction phases. First, besides the traditional requirements of designing for constructability, OSM projects need design for manufacturing and assembly (Arif et al. 2012). Design technologies and processes should be appropriately selected and arranged to facilitate the integration of design, manufacturing, and construction stages and to avoid fragmentation (Arashpour et al. 2018). Second, given the customized nature of construction projects, OSM manufacturing technologies and processes should be flexible enough to accommodate design changes and support 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 synchronization of the construction process with the manufacturing and design processes from the project's 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).

Stakeholders

Stakeholder theory states that an organization has many relationships with different groups and so considering and balancing their interests to maintain support is important. It is crucial to identify OSM stakeholders and plan appropriate strategies for their management. Based on the stakeholder concepts of Freeman (1984) and the 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 achievement of an OSM project's objective (e.g., a decision, activity, or outcome relating to an OSM project). OSM stakeholders include, but are not limited to, manufacturers, suppliers, owners, designers, contractors, clients, governments, and the public, and their identification is on a project-by-project basis (Teng et al. 2017). In practice, their concerns and expectations need to be identified, assessed, and satisfied, and they must be balanced given their profound impacts on project performance (Olander and Landin 2005).

OSM stakeholders differ from stakeholders in conventional in situ construction projects due to the differences between OSM and conventional projects (O'Connor et al. 2016). In the design stage, OSM requires its architects to be more proactive as experienced coordinators and interdisciplinary engineers through coordinating and balancing different participants' expectations and concerns (Luo et al. 2017). Also, design professionals should equip themselves with the capability of designing for manufacturability, constructability, and sustainability (Arif et al. 2012). In the manufacturing stage, design and construction personnel should adjust their terminologies and processes to align with those of manufacturers (O'Connor et al. 2016). Moreover, the addition 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 at the beginning of the design phase (Arif et al. 2012). Importantly, the behaviors 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). Construction professionals are usually involved in 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 the construction site and approaches are coordinated with other activities (Arif et al. 2012). Also, construction professionals, who are more familiar with conventional in situ construction methods, should change their mindsets to be more aware of the benefits of manufacturing so that processes are holistically managed to leverage those 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 difficult and complex management (Teng et al. 2017).

Research Method

Qualitative content analysis, used in this study, provides subjective and valid interpretations and inferences from collected data through the systematic classification of coding and identifying themes or patterns (Elo and Kyngäs 2008). Several reasons contributed to its use in this study. First, qualitative content analysis concerns the meanings, intentions, consequences, and context of collected data and reveals apparent and latent features of the literature, illuminating the central and natural features of OSM stakeholders. Additionally, it distills both explicit and inferred categories that represent similar meanings, supporting a systematic understanding of research themes and topics. Its application is, moreover, consistent with the perception of a literature review as a focus on identifying and analyzing, as well as synthetizing and reporting, data. Fig. 1 shows the procedure of qualitative content analysis.

Data Collection

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

Step 1: Retrieving

The two academic databases used for article searching were Scopus and Web of Science. Both platforms are large and influential abstract and citation databases of peer-reviewed literature indexing major construction and project management journals (Falagas et al. 2007).

The adopted search strategy used the following keywords/key phrases: *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 factors contributed to the adoption of this approach. First, there are various interchangeable OSM concepts, such as modern methods of construction, off-site prefabrication/construction/production, and industrialized building/housing (Pan et al. 2012). These and others were used in the search to ensure the comprehensiveness of results. Additionally, the term *construction* was employed instead of a stakeholder-related term because various stakeholders participate in the development of an OSM project and some have interchangeable names: client/developer/owner and the like, which raised the issue of complexity. In contrast, *construction* not only simplified the search but also ensured that the results would be narrowed down to the construction field.

The keywords adopted, *Article title*, *Abstract*, *Keywords*, and *Topic* in Scopus and Web of Science, were searched on August 2, 2017. The results were limited to engineering, economics, and technology and management, and only peer-reviewed English-language articles were retrieved. As some interchangeable keywords were not included in this round, a second-round search was conducted on October 18, 2018, in which *preassembly*, *prework*, *prefab*, *module assembly*, *modularity*, *modular methods*, and *prefabricated prefinished volumetric construction* were added. Consequently, more papers were searched for a more comprehensive review.

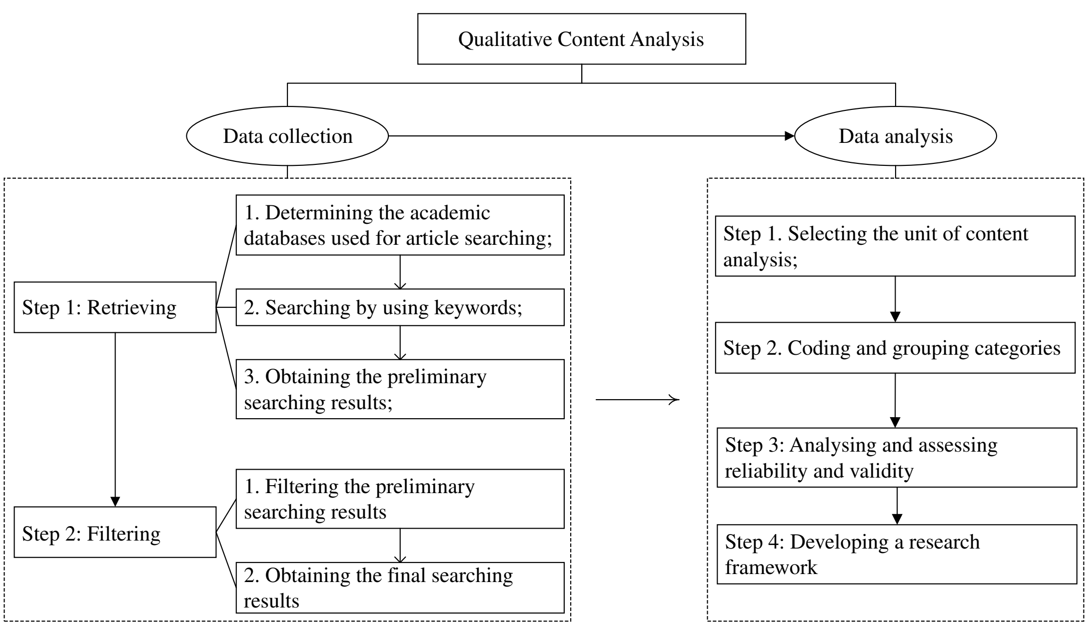

Fig. 1. Qualitative content analysis procedure.

Obtaining the preliminary search results involved 1,412 and 434 preliminary articles retrieved from Scopus and Web of Science, respectively, in the first-round research. In the second-round search, 1,613 and 507 results were retrieved from Scopus and Web of Science, respectively.

Step 2: Filtering
Filtering the preliminary search results followed the rule that a paper's topic should be closely associated with OSM stakeholders, as defined in the "Stakeholders" section in this paper. To ensure filtering quality, a two-round article selection strategy was employed. The first-round focused on *Article title*, *Abstract*, and *Keywords* to select candidate papers, followed by the second-round selection of whole articles to determine relevance. Obtaining the final search results led ultimately to 149 articles, organized and managed by Mendeley Desktop.

Data Analysis

Data analysis included selecting the unit of analysis, coding and creating categories and analyzing and assessing reliability and validity (Morgan 1993). On this basis, a research framework was proposed.

Step 1: Selecting the Unit of Analysis
A unit of analysis can be words, sentences, phrases, paragraphs, or whole text (Downe-Wamboldt 1992). Its determination 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 as context for the meaning unit. Consequently, the unit of analysis in this study was a journal paper.

Step 2: Coding and Grouping Categories
Coding and grouping were conducted through iterative reading and reviewing of the selected articles to identify significant themes and topics. A codebook was designed and used to record the main contents of articles (basic information, research content, and research theme and topic), which assisted in forming a comprehensive picture of OSM stakeholder research (Table 1). One of the authors of this paper led the coding and grouping task. The other three authors, senior researchers in the construction management field, guided and supervised it. The main reasons for using this strategy were that it avoided potential conflicting coding and grouping results from different reviewers and coders. In addition, it ensured coding quality based on the senior researchers' guidance and supervision.

Table 1. Codebook for qualitative content analysis

Code	Definition
Basic article information	Title Authors Publication in which article published Year of publication
Research content	Research problem explicitly stated Research aim explicitly stated Research method to achieve research aim Stakeholders participated in study Research findings of article Theoretical and practical contributions of article
Research theme and topic	Research focus

Step 3: Analyzing and Assessing Reliability and Validity
Article contents were retrieved and transcribed into the codebook, and a database was therefore established. The review process provided the opportunity of rechecking the reliability and validity of the codebook by the adjustment of codes. This process was guided and supervised by senior researchers. All reviews led to the refinement of the codebook to improve its reliability and validity, which ensured the quality of the data analysis results.

Step 4: Developing a Research Framework
Based on the overview of prior research and the critical review of OSM projects, a research framework revealing OSM stakeholder research topics and offering valuable insight into the three levels of industry, organization, and project was developed for OSM stakeholders' future development and improvement.

Research Overview

Distribution of Articles

One hundred and forty-nine articles were distributed across 52 journals. The main sources of these articles were *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 are leaders in the field of construction engineering and management (Wing 1997).

Publications in Years

Fig. 2 depicts the number of publications over time. Average annual publications before 2007 were less than 2 but have increased since 2007. A Mann-Whitney test was conducted using IBM SPSS Statistics 23 to examine whether or not this increase was significant. This test nonparametrically determines whether or not two samples come from the same population and does not require the assumption of normality (Rosner and Grove 1999), making it suitable for testing differences between the two publication number groups in the study. The results indicated that OSM stakeholder research has increased significantly since 2007 ($u = -4.877$, sig. $= 0.000$).

Themes and Topics

The selected OSM stakeholder studies covered the two themes of stakeholders' perceptions and behaviors and stakeholder management (Table 2). Most studies focused on OSM stakeholders' perceptions and behaviors, whereas stakeholder management research was largely underresearched. In addition, 11 specific research topics were identified, with the most popular being *perceived drivers of and barriers to OSM adoption*. Regarding stakeholder management, the mostly explored topic was *stakeholder integration, collaboration, and relationships*.

Stakeholders' Perceptions and Behaviors

Perceived Drivers of and Barriers to OSM Adoption

Many stakeholders have a positive attitude toward OSM adoption, which is in keeping with the predicted increasing take-up of OSM (Goodier and Gibb 2007; Larsson et al. 2014; Lu and Liska 2008;

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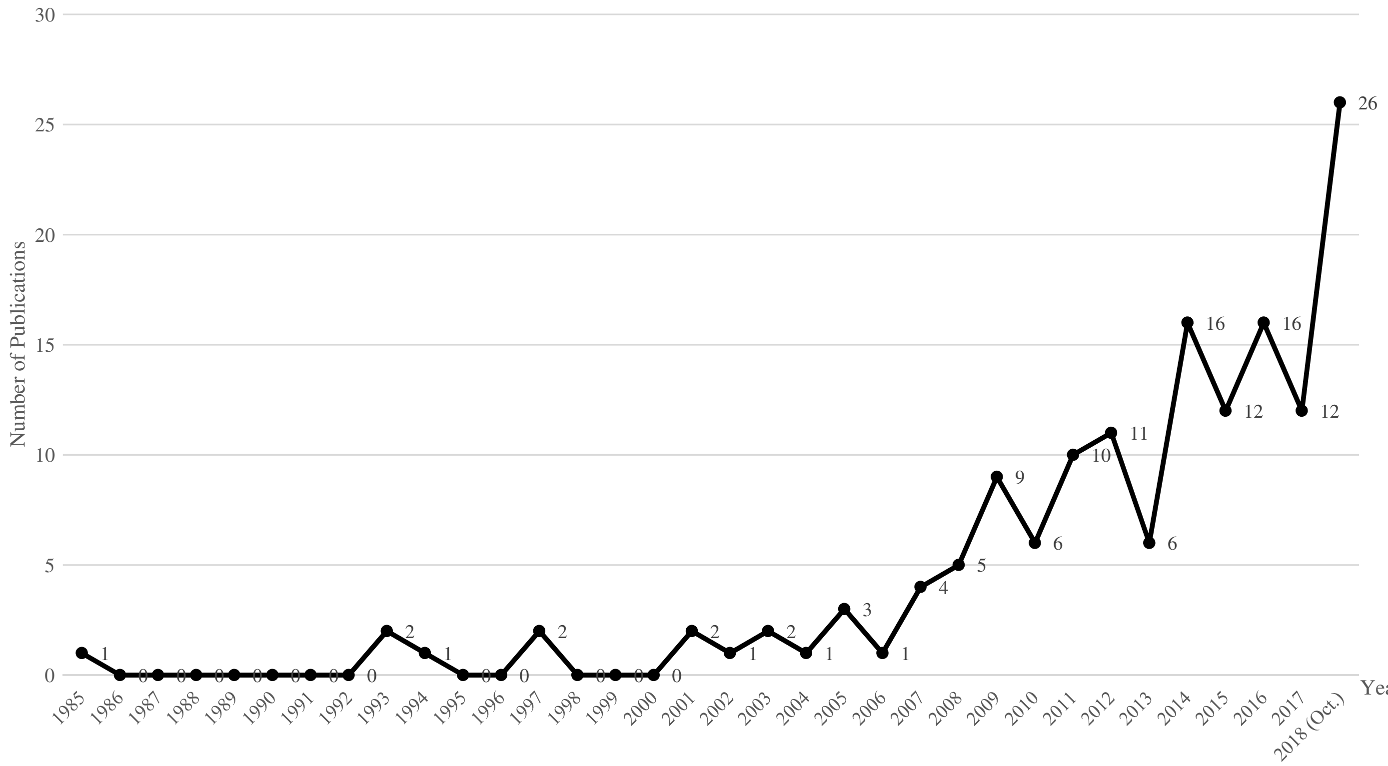

Fig. 2. Publication trend in years.

Pan et al. 2007, 2008). Stakeholder theory indicates that stakeholders' perceptions impact their corresponding behaviors, and that 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 in future OSM take-up. Larger organizations are generally more favorable to OSM due to their superiority in 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 countries believe 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, with eight specific drivers identified (Table 3). The most perceived is time benefits (e.g., shortened duration), followed by quality benefits (e.g., high product quality) and cost benefits (e.g., reduced cost). This result mirrored the importance of the conventional project management objectives of cost, time, and quality in the decision to use OSM (Gao et al. 2018). In addition, environmental sustainability benefits (e.g., waste reduction) were shown as 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

Table 2. Research themes and topics and frequency

Theme	Topic	Frequency
Stakeholders' perceptions and behaviors	Perceived drivers of and barriers to OSM adoption	45
	Stakeholders' best practices and practical strategies	34
	Perceived performance of OSM adoption and customer satisfaction	18
	Perceived OSM selection criteria	12
	Stakeholders' business models and competitive advantages	11
	Perceived OSM critical success factors	9
	Stakeholders' readiness to implement OSM	5
	Stakeholders' training and education	4
	Other	7
Stakeholder management	Stakeholders' integration, collaboration, and relationships	14
	Stakeholder identification, roles, and attributes	5
	Stakeholders' requirements and expectations	4

Note: One article may be grouped into more than one research topic groups.

Table 3. Perceived drivers of OSM adoption

	Percentage		
Driver	Overall	Developing economies	Developed economies
1. Time benefits	100.0	100.0	100.0
2. Quality benefits	91.3	91.7	90.9
3. Cost benefits	86.9	83.3	90.9
4. Environmental sustainability benefits	73.9	75.0	72.7
5. Risk, health and safety	65.2	58.3	72.7
6. Process and program advantages	65.2	58.3	72.7
7. Industry and market culture	56.5	58.3	54.5
8. Workforce and productivity	47.8	41.7	54.5

Note: Determination of developing and developed economies is based on country classification in United Nations (2017).

(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 economies view the benefits of time, cost, and quality as top drivers. In addition, compared with stakeholders in developing economies, who focus more on environmental sustainability benefits, stakeholders in developed economies place more value on risk, health and safety, and process and program advantages.

However, the benefits of OSM adoption have not been fully understood by stakeholders, leading to a cautious attitude toward OSM and slow take-up in practice (Choi et al. 2019; Gan et al. 2018a, b; Jiang et al. 2018a; 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 barriers were retrieved from 31 studies (Table 4), with the top-ranked being cost (e.g., high investment); progress and program (e.g., late design change difficulties); and knowledge, experience, and skill (e.g., experience lacking). OSM stakeholders' background (e.g., economics, country, affiliation, job, and organization size) again impacts their perceptions of barriers (Rahman 2014). As shown in Table 4, stakeholders in developing economies view knowledge and experience as the most important barrier, whereas this barrier is not as important in developed economies. In addition, compared with stakeholders in developing economies, those in developed economies view cost (e.g., high overall cost) and progress and program (e.g., inflexible regarding late changes) as two more important barriers to OSM use. To mitigate these barriers, the studies revealed that OSM stakeholders can play important roles—for example, governments, in formulating policies and regulations, and industry practitioners, in establishing proper understanding and knowledge of OSM (Hedgren and Stehn 2014; Luo et al. 2015).

Best Practices and Practical Strategies

The studies reported OSM stakeholders' best practices in some countries or regions, such as 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). They also identified various practical issues that OSM stakeholders encounter 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 modeling (BIM) (Mostafa et al. 2018a). As the adoption of OSM is a complex and multilayered structure of business management, it is crucial for OSM stakeholders to build practical strategies for their best practices (Pan et al. 2012). These 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 2001a, b; Meiling et al. 2012; Nahmens and Ikuma 2009; Nahmens et al. 2012), BIM (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 legal strategies (Mostafa et al. 2018b). For instance, Mostafa et al. (2018b) suggested using "leagile" (lean plus agile) strategies to optimize the delivery of OSM projects and a multicriterion decision-making model to facilitate their selection. The use of best practices and practical strategies is of great importance to stakeholders in practice. According to stakeholder theory, they are one source of stakeholders' competitive advantages in improving performance for survival (Laplume et al. 2008). However, in the implementation of these strategies, OSM stakeholders must 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 nonvalue activities (Senaratne and Ekanayake 2012; Wu and Feng 2014), financial difficulties, demand uncertainties, site congestion, lack of confidence (Low and Choong 2001a, b; Oral et al. 2003), difficulties in transforming customers' needs into design parameters, and conflicts between customization and efficiency (Nahmens and Bindroo 2011).

Table 4. Perceived barriers to OSM adoption

Barrier	Percentage			
	Overall	Developing economies	Developed economies	Mixed
1. Cost	97.4	96.0	100.0	100.0
2. Progress and program	92.1	88.0	100.0	100.0
3. Knowledge and experience	86.9	96.0	63.6	100.0
4. Perception, motivation, and culture	79.0	76.0	81.8	100.0
5. Industry, market, and supply chain	63.2	56.0	72.7	100.0
6. Policy and regulation	60.5	68.0	45.5	50.0
7. Technological innovation	36.9	40.0	27.3	50.0
8. Training and education	7.9	12.0	0.0	0.0

Perceived OSM Performance and Customer Satisfaction

One benefit of OSM seen by stakeholders is improved project performance, which is 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, labor reduction) were also reported (Jaillon and Poon 2008). For instance, Jaillon and Poon (2008) found that OSM use might increase unemployment in the construction industry due to reduced labor requirements on-site. OSM stakeholders also perceive a set of factors that 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). According to Alazzaz and Whyte (2015), for example, employee empowerment can help increase OSM performance by positively impacting fabrication-yard productivity.

Quality is a key consideration in stakeholders' choice of construction method. Practical evidence retrieved from Malaysia demonstrates that the quality of OSM-constructed buildings is better than the quality of those completed by traditional construction methods, which encourages stakeholders' OSM use (Ali et al. 2012). Despite this, quality problems can also result for various reasons during the design, production, and construction stages. Factors identified by Chinese construction professionals include inaccurate design of the connecting points between core components, lack of design and production norms and standards, lack of quality criteria, lack of quality management system, and lack of technical guidelines (Gan et al. 2017). The 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). The lack of specification and standards, for example, can result in issues (e.g., mismatching of precast components) that impact cost performance profoundly. Many stakeholders estimate that OSM construction is about 20% more expensive than conventional construction (Jaillon and Poon 2008). To optimize cost performance, Xue et al. (2018a) suggested collaboration management given that cost management is not a simple linear combination.

OSM stakeholders are showing increased interest 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 value all three sustainability categories: 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 indicators for the three sustainability dimensions were included, and weights were assigned 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 buildings, and affordability (Kamali et al. 2018). Notably, stakeholders are also concerned about the poor sustainability of OSM projects. For instance, some stakeholders believe that pollution from the transportation of prefabricated components is a major environmental limitation (Jaillon and Poon 2008).

Customer satisfaction is positively associated with OSM performance (McGrath and Horton 2011; Nahmens and Bindroo 2011). Although OSM-produced housing has the capability to satisfy customers' needs (Phillips et al. 2016), dissatisfactions were reported. For one, based on a postoccupancy evaluation, McGrath and Horton (2011) reported intrusive noise in an OSM-constructed student accommodation in the United Kingdom. To improve customer satisfaction in the OSM market, Azam Haron et al. (2015) developed a quality function deployment model based on the quality matrix, the function matrix, and a combination of the two. In addition, strategies were suggested to improve customer satisfaction, including policy improvement, government supervision, improved building design, standards, and quality control (Azam Haron et al. 2015).

OSM Selection Criteria

Stakeholders' decision making is usually complicated due to the technical, organizational, and environmental complexity of projects (Aaltonen and Kujala 2016). However, it seems that stakeholders tend to simplify the decision-making process in the selection of OSM. Industry evidence indicates that stakeholder decisions regarding OSM largely rely on experience or cost-related performance (Chen et al. 2010; Park et al. 2011; Steinhardt and Manley 2016). Steinhardt and Manley (2016) revealed that builders' decisions rely on attitudes, beliefs, and autonomy. However, this leads to poor implementation or project failure because the decision-making process is complicated by the need to assess various industry-related and firm-related factors (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 expert judgment (Azhar et al. 2013).

Zakaria et al. (2018) identified 14 factors that impact the decision to use OSM in the Malaysian construction sector, covering structural, contextual, and behavioral themes. Song et al. (2005) developed a decision framework to ensure a thorough assessment of influential factors (e.g., schedule, cost, labor, safety, site attributes) that are related to OSM decisions. There are other developed approaches to facilitate OSM decision making, such as feasibility prediction (Said 2016), knowledge basis (Murtaza et al. 1993), and the Knowledge-Based Decision Support System for Prefabricated Prefinished Volumetric Construction (Hwang et al. 2018b). Due to increased concerns about sustainability, Chen et al. (2010) depicted sustainability selection criteria for OSM use as social, economic, and environmental. It is also important to determine the level of modularization. To achieve this, Sharafi et al. (2018) developed a multicriterion decision analysis model including quality and safety, productivity and efficiency, cost and sustainability, and constructability and design.

Business Models and Competitive Advantages

OSM business model innovation is promoted by a favorable business environment and entrepreneurial cognition (Liu et al. 2017), where a business environment can be assessed using strengths, weaknesses, opportunities, and threats (SWOT) analysis (Li et al. 2016; Mohamad et al. 2012; Yunus and Yang 2014; Jiang et al. 2018b). In practice, OSM stakeholders require new business models, which involves change management, new relationships, skills, technology, process and working ways, and ways in which professionals interact (Goulding et al. 2015). Case studies of OSM companies in Sweden and North America have indicated that a good fit and a balance between the offering, operational platform, and market position of a business model are of great importance to success (Lessing and Brege 2018). Brege et al. (2014) proposed new business models that adapt a general business model; the feasibility of this approach has been confirmed by Swedish manufacturers.

OSM enhances contractor competitiveness by positively influencing project design, constructability, sustainability, and innovation (Chan et al. 2004). However, OSM itself is not a sustainable source of competitive advantage (Chiang et al. 2008). Instead, contractors should focus on OSM innovation such as improving the efficiency of supply chain management (Chiang et al. 2008). In practice, contractors have adopted various business strategies to attain competitive advantages such as closed supply chain loops, manufacturing investment planning, large volume and repetitive design, and providing total solutions (Kamar et al. 2012).

Perceived OSM Critical Success Factors

Critical success factors (CSFs) influencing OSM implementation have been explored based on stakeholder judgment 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 21 CSFs in the United States, with the top-ranked being module envelope limitations, team alignment on drivers, adequate owner planning resources and processes, timely scoping and design freeze, and due recognition of possible early completion. Choi et al. (2016) suggested CSFs for OSM cost and schedule success, including timely design freeze, owner-furnished/long-lead equipment specification, vendor involvement, and management of execution risks. Li et al. (2018) identified CSFs that impact OSM project planning and control; they include technology and method, information, communication and collaboration, external environment, experience and knowledge, and project manager competence.

Readiness to Implement OSM

The adoption of OSM creates a new project environment that demands its stakeholders' readiness for change. In Australia, though OSM practitioners were well aware of the need to change and had undertaken some practice alterations (e.g., revising policies and performance management systems), these changes mainly focused on planned approaches and the practitioners' emergent organizational change strategies were underdeveloped (Wong et al. 2017).

The situation was worse in some countries due to the reported unreadiness of stakeholders (e.g., contractors and architects in the Malaysian private project sector) (Nawi et al. 2015), which had resulted from lack of experience, poor communication, financial problems, and restrictions by stakeholders (Hanafia et al. 2016; Tamrin et al. 2016). To improve the situation, suggestions were proposed in terms of training, government incentives, design freeze, greater awareness, and standardization (Tamrin et al. 2016).

Stakeholders' Training and Education

OSM stakeholders acknowledge the benefits of OSM training and education (e.g., alleviating the skill shortage), and plan to invest more in training and education programs (Hanna et al. 2017; Nadim and Goulding 2009). However, traditional training and education methods have many limitations and have been criticized for being costly and limited. There is high demand for simulated onsite training. Thus, Goulding et al. (2012) developed a prototype virtual-reality interactive training environment that provides risk-free learning and experiencing. Experience from the United Kingdom indicates that building collaboration between universities and industry is an effective way to improve skill development in the workplace, including skills training content to meet the requirements of OSM (Hairstans and Smith 2018).

Stakeholder Management

Integration, Collaboration, and Relationships

There is a need to integrate OSM stakeholders in supply chains to facilitate OSM (Doran and Giannakis 2011). This is easy to understand from the perspective of stakeholder theory. Stakeholder integration allows complicated issues to be addressed through resource pooling, complementary capabilities, economies of scales, and greater innovation (Savage et al. 2010). However, this is not easy in practice because integration is complicated and impacted by humans, processes, and technologies (Nasrun et al. 2016; Nawi et al. 2011). There is consensus among stakeholders that collaboration is beneficial. For instance, Xue et al. (2018b) stated that stakeholder collaborative management (interaction frequency, emotional intensity, familiarity, and reciprocity) has a positive influence on OSM cost performance. Nevertheless, the lack of shared understanding of the preferred means of collaboration between stakeholders is a significant barrier (Nadim and Goulding 2009). London and Pablo (2017) developed an expanded theoretical and empirical conceptualization of collaboration in OSM projects on the basis of actor-network theory, which deepens the understanding of OSM stakeholder collaboration.

Qualified stakeholder relationships are the basis of project success. For a specific stakeholder, it is crucial to develop appropriate relationships with other stakeholders by eliminating separations so that alliances can develop that make good use of individual advantages and resource exchange (Aaltonen and Kujala 2016). Said (2015) reported on effective partnerships built through streamlining business and project operations in the US electrical construction sector. Teng et al. (2017) identified two OSM stakeholder relationships, positive symbiosis (e.g., owners and designers) and commensalism (owners and users) in China. OSM studies have also explored relationships between specific OSM parties, including buyers and suppliers (Bildsten 2014), contractors and subcontractors (Hsieh 1997), contractors and suppliers (Hofman et al. 2009), and manufacturers and retailers (Jeong et al. 2009). It has been revealed that standardized goods and services require a long-term and loose buyer–supplier relationship, whereas specialized solutions and services require a buyer–supplier relationship that is close and long-term (Bildsten 2014; Bildsten et al. 2011). OSM stakeholder relationships in practice have been described. For instance, in China management of general contractor–supplier relationships is low and there is a lack of organizational integration between the two (Liu et al. 2018).

Identification, Roles, and Attributes

Stakeholder identification is the first step in stakeholder analysis. Teng et al. (2017) identified a variety of stakeholders in the development of an OSM project in China based on expert judgment, including developers, suppliers, contractors, designers, users, and capital providers. One of the key requirements of identification is that it be comprehensive. Also, it should consider dynamism as different stakeholders participate in different project stages. Among these stakeholders, Luo et al. (2017) suggested that the architect role be changed from architectural work to building product and that architects should be seen as coordinators and interdisciplinary engineers to balance the demands and requirements of different parties. Gan et al. (2018a) concluded 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 habits of customers and the organizational characteristics and information and capital flow of retailers and manufacturers that benefits their management. Client order information is of great importance in managing OSM. Mostafa and Chileshe (2018) developed a discrete-event simulation model using Arena simulation software to study the impacts of client order interaction on the performance of OSM supply chains in Australia.

Requirements and Expectations

Understanding stakeholders' requirements and expectations is a key task of stakeholder analysis. Studies have 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 customers' needs encompass style, process technology, materials, performance, and functionality in the US manufactured housing market. Stakeholder theory states that different stakeholders may have conflicting expectations and concerns. It is therefore important to identify these conflicts and propose appropriate management strategies.

Research Framework

OSM stakeholders are underresearched compared with stakeholders in conventional in situ projects, with only a few topics being sufficiently explored. In addition, OSM stakeholder studies are scattered and so lack a comprehensive reach. There is a need for systemic study of OSM stakeholders, which can be assisted by developing a research framework. The term *stakeholder* should break through its original meaning (Freeman 1984) to cover a wider scope due to the multiple types of OSM stakeholder, such as industry practitioners, firms, and project participants. OSM stakeholders work as industry practitioners at the industry level, where they profoundly influence the industry's development. As construction organizations, they adopt appropriate strategies for survival in a competitive environment. At the project level, they are participants who should be well managed. In this respect, OSM stakeholders can be systematically explored using a top-down typology at the industry, organization, and project levels (Fig. 3).

This provides a framework for analyzing OSM stakeholders and offers key insights for improvement. Clearly, research at the industry and organization levels views stakeholders as practical players, whereas they are the research objective at the project level. The three levels interact. 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 project implementation. A further examination of research topics in Table 2 indicates that they can be classified into the three levels. Specifically, the perceived drivers of and barriers to OSM use and readiness to adopt OSM have been explored from the perspective of industry. The topics that make up stakeholder management are linked to the project level. Others have been studied at the organization level.

Industry Level: OSM Stakeholders as Industry Practitioners

At the industry level, research has focused on the fact that OSM is in its initial stages, revealing stakeholders' understanding of the barriers to and drivers of OSM development and their readiness to adopt it (Fig. 3). Future studies will further investigate the interaction of these barriers and drivers and their impacts on OSM development using methods such as system dynamics. Courses of action by which OSM stakeholders can be more prepared for OSM use should also be explored.

Development of the OSM industry needs to overcome various barriers including those related to its stakeholders. In developing economies in particular, research has offered the insight of enhancing industry practitioners' experience and knowledge. Abundant experience and knowledge are CSFs in OSM implementation (O'Connor et al. 2014). Nevertheless, the literature review described in this paper has revealed that a major barrier to OSM in developing economies is players' insufficient experience and knowledge (Jaillon and Poon 2010; Mao et al. 2015; Sadafi et al. 2011). Two strategies for overcoming these obstacles are training and education programs and learning from other countries.

In developed economies, the situation changes. More effort should be focused on changing industry players' negative perceptions of OSM. The negative image of OSM products, grounded in the historical failure of off-site practices rather than technical barriers, has been rooted in the mindset of industry players, leading to their resistance to OSM (Goodier and Gibb 2007; Steinhardt and Manley 2016). Strategies for improving this situation include applying both hard and soft technologies, demonstrating OSM product performance, and providing practical OSM examples.

Government policy plays a foundational role in industry development. Though the OSM sector has been developing for many years, many studies from both developing and developed economies reveal that poor policies are still hindering its development (e.g., Larsson et al. 2014; Mao et al. 2015). Therefore, there is a need to revisit and review government policies and propose appropriate ones as a new, positive starting point. It is especially important that such policies coordinate the different elements of industry development (innovation, technology, resources, employment) at the different OSM stages (manufacturing, transportation, construction, and maintenance). This will be a crucial component in a supportive OSM environment that removes barriers and better prepares stakeholders for OSM implementation.

Organization Level: OSM Stakeholders as Organizations for Survival

At the organization level, OSM research can be grouped into three dimensions: decision making, process, and outcome (Fig. 3). However, the majority of the studies investigated dealt with only one of these, although in fact they are all interrelated. Decision making influences outcomes indirectly by directly impacting process. Future studies should investigate the interaction and integration of the three OSM dimensions to facilitate in-depth understanding of OSM stakeholders at the organization level.

There is consensus among researchers that, because many parties participate in the development of an OSM project, a collaborative environment is necessary to efficiently coordinate their interests (Hofman et al. 2009). However, this has been largely hindered by the lingering use of conventional procurement systems (CPSs), which raise incompatibility issues (Pan et al. 2007). First, there is a potential conflict between the magnified importance of the OSM off-site production stage, which is relatively ignored in CPSs. In addition, compared with conventional in situ projects, the responsibilities and authorities of parties in OSM are different and their determination is more complicated. This brings the challenge of assigning the right responsibilities and authorities to OSM players when CPSs are adopted. Moreover, implementation of

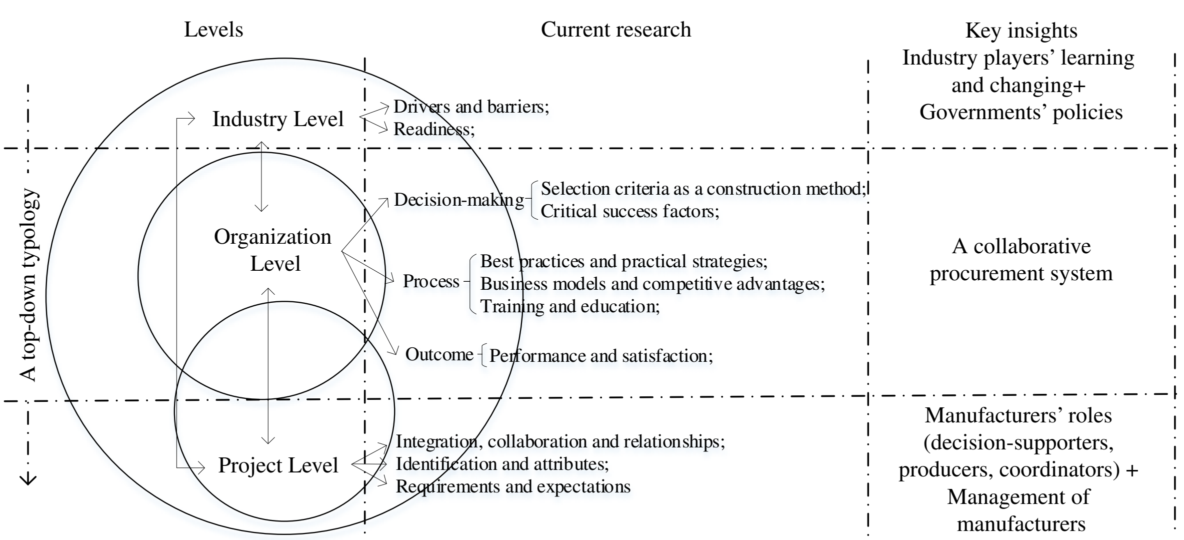

Fig. 3. Research framework.

OSM demands that parties build more collaborative and integrated relationships, which is hardly achieved when using CPSs. Consequently, improving procurement (Pan et al. 2007) or exploring alternative forms of procurement (Blismas and Wakefield 2009) is necessary.

Collaboration has been identified as a facilitator of OSM, as helping to change problem-addressing behavior, and as a crucial component in OSM practitioners' relationships (London and Pablo 2017). All of these promote collaboration in OSM procurement. Key issues that should be of concern in the design of this collaborative procurement system are (1) early integration of OSM parties (especially manufacturers, designers, and contractors) and their coordination and collaboration; (2) appropriate assignment of responsibilities and authority to OSM parties; (3) control of the off-site production stage and its integration with on-site stages; (4) proactive OSM roles; (5) effective flow of information and resources between OSM parties during the project life cycle; and (6) effective communication trust, and commitment across interfaces.

Project Level: OSM Stakeholders as Project Participants Being Managed

OSM stakeholders have been underresearched at the project level. Future studies should follow the stakeholder management procedure suggested by the Project Management Institute (2013) to comprehensively grasp OSM stakeholder management, which includes identification, planning, engagement, and control.

Manufacturers are crucial stakeholders in OSM compared with their importance in conventional in situ construction projects, mainly due to the magnified importance of off-site production activities. Their responsibilities and authorities differ from those they have in traditional projects. Therefore, there is a need for revisiting and reviewing the roles that manufacturers play in OSM practice. Preliminary thinking, based on literature review, is that they should play at least three roles during the life cycle of an OSM project: decision supporter, producer, and coordinator. First, manufacturers ought to be integrated early into OSM practice as decision supporters who offer suggestions and advice to owners and designers. Additionally, because they are located at the center of the off-site production stage, they are producers. Moreover, they should be coordinators, connecting off-site and on-site activities to facilitate 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 aid them in responding to their roles as decision supporters, producers, and coordinators.

Discussions and Contributions

The conclusion of this study that OSM stakeholders have been underresearched is consistent with the conclusions of Hosseini et al. (2018) and Li et al. (2014) that stakeholders are not a main OSM research area. In fact, OSM studies have focused more on the hard aspects of OSM (e.g., concrete and production planning) to the neglect of the strategic aspects such as stakeholder management (Hosseini et al. 2018). This neglect hinders understanding of OSM stakeholders, ultimately harming development of the OSM sector (O'Connor et al. 2016). Future studies should follow the suggested directions as discussed at the industry, organization, and project levels.

By incorporating the industry and organization levels into the typology of OSM research along with the project level, the proposed research framework break throughs traditional perceptions that primarily restrict stakeholder issues to the project level (Aaltonen and Kujala 2016). In fact, the stakeholder issue is closely associated with industry and organization development as widely evidenced in the strategic management literature (Chinowsky and Meredith 2000; Fox and Skitmore 2007). Investigation of OSM stakeholders at the three levels deepens understanding in a comprehensive way, which is especially valuable given that the OSM sector is in its initial stages. The insights provided at the three levels are conceptual, requiring greater efforts to detail, test, and validate.

Apart from the review and analysis of stakeholders in 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, up to now, unchanged range of project stakeholder research. It represents an advancement in project management literature through systemic analysis from the both macroscopic and the microscopic perspective. Regarding practical contributions, this study will enhance industry practitioners' grasp of OSM stakeholders based on the historical literature summarized here. In addition, the insights offer practical suggestions on the future development and improvement of OSM practitioners. All of these will support the development of the OSM industry and the management of OSM stakeholders.

Conclusions

Stakeholders are a key component in the success of construction projects, and their perceptions and behaviors impact project performance profoundly. This study has offered a critical review of historical OSM stakeholder studies based on qualitative content analysis of selected journal papers. The research results have revealed 11 research topics within the research streams of stakeholder perceptions and behaviors and stakeholder management. The research has also developed a framework based on a top-down typology of industry, organization, and project which will benefit understanding of OSM stakeholder issues.

Based on the literature review here, a variety of research gaps can be identified. At the industry level, interactions between stakeholders' perceived factors impacting industry development are still not clear; nor is it clear how these factors impact stakeholders' readiness to adopt OSM. Future studies should address this gap using methods such as system dynamics, which models large-scale socioeconomic systems. This approach focuses on the interactions among physical processes, information flows, and managerial policies to measure the interplay of different components and their dynamic impacts (Vlachos et al. 2007). At the organization level, research has ignored interactions between stakeholder decision making, processes, and outcomes, instead focusing on one dimension only. Future organization-level studies should integrate the three dimensions to achieve a comprehensive understanding of OSM stakeholder competition and survival as organizations. At the project level, research has neglected OSM stakeholder management. Future studies should focus on the key issues of OSM stakeholder identification, stakeholder management planning, stakeholder engagement management, and stakeholder engagement control.

The proposed research framework was developed from the tripartite perspective of OSM industry, organization, and project. It is also meaningful to discuss OSM stakeholders from the perspective of project life cycle. For instance, future studies should classify OSM stakeholders at different project stages in visualizing and mapping stakeholder influence. Suggestions have been offered regarding the future development and improvement of OSM stakeholders. Future studies should investigate such questions as how to promote stakeholder learning and role changing at the industry level, how to ensure that governments enact suitable policies to facilitate OSM use, how to develop collaborative procurement systems to integrate stakeholders, and how to define manufacturers' roles in OSM projects.

One limitation of this study it is that it focused on journal papers; conference papers, reports, and online materials that may have provided additional insights into OSM stakeholders were not included. In addition, research findings are commonly fragmented, making it rather difficult to cover their every detail. These limitations will be rectified in future work. Notwithstanding, this research contributes to a better understanding of the stakeholder issue in OSM practice.

Data Availability Statement

Data generated or analyzed during the study are available from the corresponding author by request. Information about the *Journal*'s data-sharing policy can be found here: https://ascelibrary.org/doi/10.1061/(ASCE)CO.1943-7862.0001263.

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