

1 Understanding stakeholders in off-site manufacturing: A literature review

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12 **Abstract**

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

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

## 27 **Introduction**

28 The construction industry has long been criticized for its poor productivity and sustainability (Fulford  
29 and Standing 2014). Initiatives were launched to improve the performance and image of the industry,  
30 including off-site manufacturing (OSM) (Taylor 2010). OSM is an innovative construction method  
31 where components, elements or modules are produced and assembled in an off-site factory environment  
32 before their final on-site installation. Though the take-up of OSM is still limited, the construction  
33 industry worldwide shows an increased interest in its adoption due to the benefits it brings (e.g.,  
34 improved sustainability and productivity) (Hosseini et al. 2018). For instance, in the United Kingdom  
35 (UK), the government acknowledged that the adoption of OSM is a tenet of improving the quality and  
36 efficiency of its construction sector, and its volume increased by £4 billion during 2004-2006 (Goodier  
37 and Gibb 2007). In Australia, the use of OSM was recognized as a key vehicle for driving the  
38 development of its property and construction industry over the next decades (Hampson and Brandon  
39 2004).

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

52 review of OSM stakeholders is still lacking. This lack hinders the in-depth understanding of the nature  
53 of OSM stakeholders and the suggestions of OSM stakeholder management strategies.

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

## 60 **The Stakeholder Theory**

61 The ‘stakeholder’ concept in the management literature can be traced back to an internal memorandum  
62 at the Stanford Research Institute in 1963, where stakeholders were originally defined as ‘those groups  
63 without whose support the organization would cease to exist’ (Freeman 1984) and the continued  
64 ‘survival’ is the core of the concept. The development of the stakeholder theory then fell into the four  
65 groups of corporate planning, systems theory, corporate social responsibility and organizational theory  
66 (Elias et al. 2002). In 1984, Freeman’s landmark book *Strategic Management: A Stakeholder Approach*  
67 was published and provided a solid theoretical basis for the stakeholder theory. In this book, Freeman  
68 (1984) defined stakeholders as ‘any group or individual who can affect or is affected by the achievement  
69 of the organization’s objective’ and constructed a stakeholder management framework in which the  
70 three levels of analysis must be consistent, including rational, process, and transactional. Subsequently,  
71 the stakeholder theory was advanced and justified from the three perspectives of descriptive (how firms  
72 behave), instrumental (how behaviour affects performance), and normative (how firms should behave)  
73 (Donaldson and Preston 1995). Further, the recognition of the dynamics of stakeholders contributed to  
74 Mitchell et al., (1997)’s stakeholder typology and Rowley (1997)’s network theory of stakeholder  
75 influences. More recently, more stakeholder theories were developed and empirical studies were  
76 conducted, which is termed as a period of ‘maturity’ by Laplume et al. (2008).

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

## 92 **OSM Projects and Stakeholders**

### 93 ***OSM Projects***

94 OSM is defined as the construction method of manufacturing components, elements or modules in an  
95 off-site factory environment away from the project site, and assembling them on-site (Taylor 2010).  
96 The benefits of adopting OSM had been well documented, such as minimized on-site operations, less  
97 congestion on-site, improved health and safety, increased predictability and efficiency, and added value  
98 (CIRIA 1999; Gibb and Isack 2003). However, OSM use is not an antidote to the construction sector.  
99 Issues resulted from its adoption were reported, such as more efforts into pre-project planning and  
100 difficulties of late design changes (Kamali and Hewage 2016). Consequently, although there is a  
101 growing interest of adopting OSM due to its inherent superiority, its uptake is still low (Nadim and  
102 Goulding 2011). More efforts (e.g., addressing process, value, supply chain, and knowledge constraints

103 in the use of OSM) are needed to contribute to the transformation from the conventional in-situ  
104 construction to OSM (Blismas et al. 2005). Some research works including industry reports have been  
105 produced to promote the use of OSM. For instance, Tatum et al (1987) investigated the constructability  
106 improvement issue by adopting OSM (e.g., guidelines of OSM use in the early stages of a project). In  
107 2002, Construction Industry Institute (CII) proposed a framework for OSM decision-making, including  
108 a decision-timing map, a flow chat, tools for strategic analysis, and suggestions for a more detailed  
109 tactical analysis (CII 2002). Moreover, CII also suggested five solution elements to create an optimal  
110 environment for OSM use, covering the areas of business case process, execution plan differences,  
111 crucial success factors, standardization strategy, and modularization maximization enablers (CII 2013).

112 OSM projects have unique features compared with the conventional in-situ ones in the design,  
113 manufacturing, and construction phases. First, besides the traditional requirements of designing for  
114 constructability, OSM projects additionally need design for manufacturing and assembly (Arif et al.  
115 2012). Design technologies and process should be appropriately selected and arranged to facilitate the  
116 integration of the design, manufacturing and construction stages and avoid fragmentation (Arashpour  
117 et al. 2018). Second, given the customized nature of construction projects, manufacturing technologies  
118 and process of OSM should be flexible enough to accommodate design changes and support the  
119 implementation of a justifiable level of automation or mechanization (Arif et al. 2012). Third, the very  
120 different way of developing an OSM project, where large components and modules are assembled like  
121 toy blocks, needs synchronize the construction process with the manufacturing and design processes  
122 from early stages (O'Connor et al. 2016). Also, construction technologies should facilitate the effective  
123 interaction of the construction process with the manufacturing and design processes and offer deeper  
124 insights into decisions (Arif et al. 2012).

### 125 *OSM Stakeholders*

126 The stakeholder theory indicates that an organization has many relationships with different groups, and  
127 considering and balancing their interests to maintain support is important. Thus, it is crucial to identify  
128 OSM stakeholders and plan appropriate strategies for their management. Based on the “stakeholder”

129 concepts as defined in Freeman (1984) and Project Management Institute (2013), OSM stakeholders  
130 are defined as any individuals, groups or organizations who can affect, be affected by, or perceive  
131 themselves to be affected by the achievement of an OSM project's objective (e.g., a decision, activity,  
132 or outcome of an OSM project). OSM stakeholders are, but not limited to, manufacturers, suppliers,  
133 owners, designers, contractors, clients, governments, and the public, and their identification is project-  
134 by-project based (Teng et al. 2017). In practice, their concerns and expectations need be identified,  
135 assessed, and satisfied or balanced given their profound impacts on project performance (Olander and  
136 Landin 2005).

137 OSM stakeholders differ from those in the conventional in-situ construction projects due to the  
138 differences between OSM projects and conventional ones (O'Connor et al. 2016). In the design stage,  
139 OSM requires its architects' roles to be more proactive as experienced coordinators and  
140 interdisciplinary engineers through coordinating and balancing different participants' expectations and  
141 concerns (Luo et al. 2017), and design professionals should equip themselves with the capability of  
142 designing for manufacturability, constructability, and sustainability (Arif et al. 2012). Second, in the  
143 manufacturing stage, design and construction personal should adjust their terminologies and processes  
144 to liaise with that of manufacturers (O'Connor et al. 2016). Also, the adding of the manufacturing stage  
145 means that more parties participate in the development of an OSM project, and it is crucial to ensure  
146 that all of them are involved in the project right at the beginning of the design phase (Arif et al. 2012).  
147 Importantly, the behaviours and attitudes of manufacturers and suppliers should be paid more attention  
148 and their early integration into the OSM supply chain should be ensured (Bildsten 2014; Jeong et al.  
149 2009). Third, construction professionals are usually involved into the development of a traditional  
150 project after the design stage, whereas the development of an OSM project requires their integration at  
151 early stages to ensure that construction site and approaches are coordinated with other activities (Arif  
152 et al. 2012). Also, construction professionals, who are more familiar with the conventional in-situ  
153 construction method, should change their mind-sets to be more aware of the benefits of manufacturing  
154 so that processes are holistically managed to leverage these benefits (Arif et al. 2012). To manage OSM  
155 stakeholders effectively, it is imperative to plan innovative strategies, such as partnerships (Jeong et al.

156 2009). However, this is not easy as increased coordination among OSM stakeholders is required and  
157 the complicated relationships between them lead to the difficulty and complexity of management (Teng  
158 et al. 2017).

## 159 **Research Method**

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

170 *<Insert Fig. 1 here>*

## 171 **Data Collection**

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

### 175 **Step 1: Retrieving**

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

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

202 *Obtaining the preliminary searching results.* 1,412 and 434 preliminary articles were retrieved  
203 from Scopus and Web of Science respectively in the first round research. In the second round search,  
204 1613 and 507 results were retrieved from Scopus and Web of Science respectively.

205 Step 2: Filtering



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

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

#### 214 ***Data Analysis***

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

##### 218            Step 1: Selecting the unit of content analysis

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

##### 226            Step 2: Coding and grouping categories

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

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

236 <Insert Table 1 here>

237 Step 3: Analysing and assessing reliability and validity

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

244 Step 4: Developing a research framework

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

249 **Overview of Research on OSM Stakeholders**

250 *Distribution of the Articles*

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

256 ***Publications in Years***

257 Fig. 2 depicts the number of publications over time. The average annual publication number before  
258 2007 was less than 2 but has increased since 2007. A Mann-Whitney U test was conducted by adopting  
259 the IBM SPSS Statistics 23 program to examine whether the increase is significant or not. The Mann-  
260 Whitney U test was used as it is a non-parametric test adopted for testing whether two samples come  
261 from the same population and it does not require the assumption of normality (Rosner and Grove 1999),  
262 which is suitable for testing differences between the two “publication number” groups in the study. The  
263 results indicated that the number of the OSM stakeholder research has increased significantly since  
264 2007 ( $u=-4.877$ ,  $\text{Sig.}=0.000$ ).

265 *<Insert Fig. 2 here>*

266 ***Research Themes and Topics***

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

273 *<Insert Table 2 here>*

274 **Overview of the OSM Stakeholder Research**

275 ***Stakeholders’ Perceptions and Behaviours***

276 ***Perceived Drivers and Barriers of OSM Adoption***

277 Many stakeholders hold a positive attitude towards OSM adoption, with the predicted increasing take-  
278 up of OSM (Goodier and Gibb 2007; Larsson et al. 2014; Lu and Liska 2008; Pan et al. 2007, 2008).  
279 The stakeholder theory indicates that stakeholders’ perceptions impact their corresponding behaviours,

280 and a positive perception tends to result in a positive result (Olander and Landin 2005). Consequently,  
281 it is reasonable to state that there can be seen an increase of the future OSM up-take in practice given  
282 the identified positive attitudes of OSM stakeholders to OSM use. Larger organizations are generally  
283 more favourable to OSM use due to their superiority in the overall project delivery and construction  
284 methods (Hanna et al. 2017; Pan et al. 2007; Rahman 2014). Stakeholders from industrialized countries  
285 tend to believe that industry practitioners contribute more to the take-up of OSM (Goodier and Gibb  
286 2007; Said 2016), whereas those in developing economics state that governments play more crucial  
287 roles in the process (Zhai et al. 2014).

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

302           *<Insert Table 3 here>*

303           However, the benefits of OSM adoption have not been fully understood by stakeholders,  
304 leading to their prudent attitude towards OSM and a slow take-up in practice (Choi et al. 2018; Gan et  
305 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

332 stakeholders to build practical strategies for their best practices (Pan et al. 2012). Some of the reported  
333 practical strategies and best practices include supply chain strategy (Jeong et al. 2009; Kamar et al.  
334 2012; Pan et al. 2012; Zhai et al. 2017), production elements forecasting (Dawood and Neale 1993;  
335 Sing et al. 2014), lean production (Low and Choong 2001b, 2001a; Meiling et al. 2012; Nahmens and  
336 Ikuma 2009; Nahmens et al. 2012), BIM use (Mostafa et al. 2018a), customization (Nahmens and  
337 Bindroo 2011; Wikberg et al. 2014), risk management (Hassim et al. 2009; Kim et al. 2012; Li et al.  
338 2013; Shaari et al. 2016), standardization (O'Connor et al. 2015), and leagile strategies (Mostafa et al.  
339 2018b). For instance, Mostafa et al. (2018b) suggested using leagile strategies to optimize the delivery  
340 of OSM projects and a multi-criteria decision-making model were proposed to facilitate decision-  
341 makers' selection of specific strategies. The use of best practices and practical strategies is of great  
342 importance to stakeholders in practice. Especially, according to the stakeholder theory, they are one of  
343 the sources of stakeholders' competitive advantages to improve their performance for survival  
344 (Laplume et al. 2008). However, in the implementation of these strategies, OSM stakeholders need  
345 overcome problems such as poor stock management (Wu and Low 2014), conventional production  
346 culture and site-based mentality (Höök and Stehn 2008), negative impacts of non-value activities  
347 (Senaratne and Ekanayake 2012; Wu and Feng 2014), financial difficulties, demand uncertainties, site  
348 congestion, confidence lacking (Low and Choong 2001b, 2001a; Oral et al. 2003), difficulties of  
349 transforming customers' needs into design parameters, and conflicts between customization and  
350 efficiency (Nahmens and Bindroo 2011).

### 351 *Perceived Performance of OSM Adoption and Customer Satisfaction*

352 The benefits of the OSM construction method lead industry stakeholders believe that its use can improve  
353 project performance, which was confirmed by practical experience (e.g., improved productivity and  
354 sustainability) (Badir et al. 2002; Hanna et al. 2017; Jaillon and Poon 2008; Jeong et al. 2009). However,  
355 some performance limitations (e.g., high cost, pollution, and labour reduction) were also reported  
356 (Jaillon and Poon 2008). For instance, Jaillon and Poon (2008) found that OSM use might increase the  
357 unemployment rate in the construction industry due to the reduction of labour requirement on-site. OSM

358 stakeholders also perceived a set of factors that can impact the performance of OSM projects, with the  
359 important ones being time, safety, buildability, and employee empowerment (Alazzaz and Whyte 2015;  
360 Yunus and Yang 2014). For example, Alazzaz and Whyte (2015) revealed that employee empowerment  
361 can help increase the performance of OSM projects through positively impacting fabrication-yard  
362 productivity levels.

363           Quality is a key consideration when stakeholders determine their construction method. Practical  
364 evidence retrieved from Malaysia demonstrates that the quality of OSM-constructed buildings is better  
365 than those constructed by traditional construction methods, which encourages stakeholders' future OSM  
366 use (Ali et al. 2012). Despite so, quality problems can also be resulted from various factors during the  
367 design, production and construction stages. For instance, the factors identified by Chinese construction  
368 professionals include inaccurate design of the connecting points between core components, lacking  
369 design and production norms and standards, lacking quality criteria, lacking quality management system,  
370 and lacking construction technical guidelines (Gan et al. 2017). Cost performance of OSM projects is  
371 impacted by factors such as “specification and standards for prefabricated building design”, “related  
372 experience of manager”, and “rationality of precast component split” (Xue et al. 2017). For instance,  
373 the lack of specification and standards can result in issues (e.g., mismatching of precast components)  
374 which further impact the cost performance of OSM projects profoundly. Many stakeholders estimated  
375 that OSM construction is about 20% more expensive than conventional construction (Jaillon and Poon  
376 2008). To optimize cost performance, (Xue et al. 2018a) suggested the strategy of collaboration  
377 management given that cost management is not a simple linear combination.

378           OSM stakeholders are showing increased interests in the sustainability performance of OSM  
379 projects, with the perceived influencing factors being waste generation and disposal, and material  
380 consumption (Yunus and Yang 2014). OSM stakeholders valued all the three sustainability categories  
381 of social, environmental, and economic (Kamali and Hewage 2017; Švajlenka and Kozlovská 2018a).  
382 Kamali et al. (2018) developed a life cycle sustainability performance assessment framework for OSM  
383 projects. In this framework, suitable sustainability performance indicators under the three sustainability

384 dimensions were included, and the weights of indicators were assigned by using the Analytic Hierarchy  
385 Process. For instance, the top-ranked indicators in the social sustainability dimension include workforce  
386 health and safety, safety and security of building, and affordability (Kamali et al. 2018). It should be  
387 noted that stakeholders are also concerned about the poor sustainability of OSM projects. For instance,  
388 some stakeholders believed that the pollution resulted from transportation of prefabricated components  
389 is a major environmental limitation of OSM (Jaillon and Poon 2008).

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

#### 400 *Stakeholders' Selection Criteria of OSM as a Construction Method*

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



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

#### 423 *Stakeholders' Business Models and Competitive Advantages*

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

434 The use of OSM enhances contractors' competition capabilities through positively influencing  
435 their projects' design, constructability, sustainability, and innovation (Chan et al. 2004). However, OSM

436 itself is not a sustainable source of contractors' competitive advantages (Chiang et al. 2008). Instead,  
437 contractors should focus on the innovation of the OSM process such as improving the efficiency of their  
438 supply chain management (Chiang et al. 2008). In practice, contractors had adopted various business  
439 strategies to attain competitive advantages such as close supply chain loop, investment planning of  
440 manufacturing factory, huge volume and repetitive design, and being a total solution provider (Kamar  
441 et al. 2012).

#### 442 *Perceived Critical Success Factors of OSM Implementation*

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

#### 454 *Stakeholders' Readiness to OSM Implementation*

455 The adoption of OSM creates a new project environment that demands its stakeholders' readiness to  
456 change. In Australia, though OSM practitioners were well aware of the need to change and had  
457 undertook some practice changes (e.g., revising policies and performance management systems), these  
458 changes mainly focused on planned approaches and their emergent organizational change strategies  
459 were underdeveloped (Wong et al. 2017). The situation was worse in some countries due to the reported  
460 un-readiness of their stakeholders (e.g., the contractors and architects in the Malaysian private project  
461 sector) (Nawi et al. 2015), which were resulted from experience lacking, poor communication, financial

462 problems, and restrictions from stakeholders (Hanafia et al. 2016; Tamrin et al. 2016). To improve the  
463 situation, suggestions were proposed in terms of training, government incentives, design freeze,  
464 awareness improvement, and standardization (Tamrin et al. 2016).

#### 465 *Stakeholders' Training and Education*

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

#### 475 *Stakeholder Management*

##### 476 *Stakeholders' Integration, Collaboration and Relationships*

477 There is a need of integrating OSM stakeholders in supply chain to facilitate OSM use (Doran and  
478 Giannakis 2011). This is easy to understand from the perspective of the stakeholder theory. Stakeholder  
479 integration can facilitate the address of complicated issues through pooling resources, capitalizing on  
480 complementary capabilities, achieving economics of scales, and enhancing innovation (Savage et al.  
481 2010). However, this is not easy in practice as the integration is complicated and impacted by human,  
482 process, and technologies (Nasrun et al. 2016; Nawi et al. 2011). The collaboration between OSM  
483 stakeholders is a consensus due to its benefits. For instance, Xue et al. (2018b) stated that stakeholder  
484 collaborative management (interaction frequency, emotional intensity, familiarity, and reciprocity) has  
485 a positive influence on OSM projects' cost performance. Nevertheless, the lack of shared understanding  
486 of the preferred means for collaboration between stakeholders was a significant barrier of collaboration

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

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

#### 506 *Stakeholder Identification, Roles and Attributes*

507 Stakeholder identification is the first step of stakeholder analysis. Teng et al. (2017) identified a variety  
508 of stakeholders in the development of an OSM project in China based on experts' judgement, including  
509 developers, suppliers, contractors, designer, users, and capital provider. One of the key issues in the  
510 identification process is that the identified stakeholders should be comprehensive. Besides, stakeholder  
511 identification should consider the dynamism issue as different stakeholders participant in different  
512 project stages. Among these stakeholders, Luo et al. (2017) suggested that architects' roles should be

513 changed from an ‘architectural work’ mode to a ‘building product’ mode as coordinators and  
514 interdisciplinary engineers to balance the demands and requirements of different parties. Gan et al.  
515 (2018a) indicated that the government and developers hold a central position in the stakeholder network  
516 of an OSM project, indicating their great impacts on OSM project implementation. Jeong et al. (2006)  
517 explored the characteristics and purchasing process of customers, and the organizational characteristics,  
518 information and capital flow of retailers and manufacturers, which benefits their management. Client  
519 order information is of great importance in managing the OSM system. Mostafa and Chileshe (2018)  
520 developed a discrete-event simulation model by using Arena simulation software to study the impacts  
521 of client order interaction on performance of OSM supply chain in the Australian context.

#### 522 *Stakeholders’ Requirements and Expectations*

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

#### 531 **A Research Framework for OSM Stakeholders**

532 OSM stakeholders are under-researched compared with those in the conventional in-situ projects, with  
533 only a few topics being insufficiently explored. In addition, the OSM stakeholder studies are scattered,  
534 which lacks an exhaustive grasp. There is a need of systemically studying the OSM stakeholder issue,  
535 which can be assisted by developing a research framework. The term ‘stakeholder’ should breakthrough  
536 its original meaning that was defined by Freeman (1984) to cover a wider scope due to the multiple  
537 roles that OSM stakeholders play in the OSM practice such as industry practitioners, firms, and project  
538 participants. OSM stakeholders work as industry practitioners at the industry level and can influence

539 the industry development profoundly. As construction organizations, they adopt appropriate strategies  
540 for survival in a competitive environment. At the project level, they are project participants who should  
541 be well managed. In this respect, the OSM stakeholder issue can be systematically explored by using  
542 the top-down typology at the industry, organization, and project levels (Fig. 3). It provides an analytical  
543 framework to grasp the nature of OSM stakeholders and offers key insights for their improvement.  
544 Clearly, the research at the industry and organization levels views stakeholders as players of practical  
545 activities, whereas they themselves are the research objective at the project level. The three levels are  
546 interacted. For instance, an OSM stakeholder with core competence and competitive advantages is more  
547 likely to be the benchmark of the industry and has more power to impact the process of project  
548 implementation. A further examination of the research topics in Table 2 indicated that these topics can  
549 be classified into these three levels. Specifically, the perceived drivers and barriers of OSM use and the  
550 readiness to OSM adoption were explored from the perspective of industry. The topics of stakeholder  
551 management are linked to the project level. Others were studied at the organization level.

552 <Insert Fig. 3 here>

### 553 ***Industry Level: OSM Stakeholders as Industry Practitioners***

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

560 The development of the OSM industry needs overcome various barriers including those that  
561 are related to OSM stakeholders. Specially, in the developing economics, the prior studies offer the  
562 insight of enhancing industry practitioners' experience and knowledge. Abundant experience and  
563 knowledge of practitioners are a CSF of implementing OSM (O'Connor et al. 2014). Nevertheless, the  
564 review revealed that a major barrier to OSM use in the developing economics is their players'

565 insufficient experience and knowledge (Jaillon and Poon 2010; Mao et al. 2015; Sadafi et al. 2011). As  
566 part of relieving the issue, delivering training and education programs, and learning from other countries  
567 are two strategies. In the developed economics, the situation changes. More efforts should focus on  
568 changing the industry players' negative perceptions of OSM and improving their motivations for OSM  
569 use. The negative image of OSM products, grounded in the historical failure of off-site practises rather  
570 than technical barriers, has been rooted in the mind-set of the industry players, which leads to their  
571 resistance to OSM use (Goodier and Gibb 2007; Steinhardt and Manley 2016). Some of the strategies  
572 of improving this situation are applying both hard and soft technologies, demonstrating performance of  
573 OSM products, and delivering sites with practical OSM examples.

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

#### 584 ***Organization Level: OSM Stakeholders as Organizations for Survival***

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

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

#### 614 ***Project Level: OSM Stakeholders as Project Participants Being Managed***

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



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

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

## 636 **Discussions and Contributions**

637 The under-researched conclusion of this study is consistent with the review results of Hosseini et al.  
638 (2018) and Li et al. (2014) that the stakeholder issue is not identified as a main OSM research area. In  
639 fact, the prior OSM studies focused more on the 'hard' aspects of OSM (e.g., concrete and production  
640 planning), whereas strategic aspects, such as stakeholder management, were not positioned as central  
641 areas (Hosseini et al. 2018). This gap hinders the understanding of OSM stakeholders, which will  
642 ultimately harm the development of the OSM sector (O'Connor et al. 2016). The future studies can

643 follow the suggested directions as discussed at the three levels of industry, organization, and project in  
644 the above section.

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

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

## 662 **Conclusions**

663 Stakeholders serve as a key component to the success of projects, and their perceptions and behaviours  
664 impact project performance profoundly. This study offers a critical review of the historical OSM  
665 stakeholder studies based on the qualitative content analysis of selected journal papers. The research  
666 results revealed eleven research topics of OSM stakeholders within the two research streams of  
667 stakeholder perceptions and behaviours and stakeholder management. The research also developed a

668 research framework based on the top-down typology of the three levels of industry, organization and  
669 project, which would benefit the understanding of the OSM stakeholder issue.

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

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

#### 699 **Data Availability Statements**

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

#### 701 **Acknowledgement**

702 This work was supported by the Australian Research Council [grant number DP170104612].

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