Adopting off-site construction into the Saudi Arabian construction industry

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This study examined the relationship and hierarchy among the factors that enable the adoption of off-site construction into the Kingdom of Saudi Arabia (KSA) construction industry. This study used interviews with the industry's key stakeholders to identify enablers for adopting off-site construction. A questionnaire survey of construction practitioners then verified the results. It was then followed by pairwise comparison questionnaires distributed to the interviewees to develop a model using the interpretive structural model (ISM). Ten enablers were identified from interviews, which were then verified by a questionnaire survey of construction practitioners. From the ten enablers, a hierarchical framework was formed for its implementation. The results culminated in developing an ISM for a strategy in off-site construction in the KSA. The model provides a practical framework for the relevant government authorities and other key stakeholders to focus on those factors that must be prioritised to adopt off-site construction successfully.

Notation

A	if factor j will help achieve factor i
N	number of enablers between which the relationships would be investigated
O	if factors i and j will not help achieve each other or are unrelated
X	if factors i and j will help achieve each other
V	if factor i will help achieve factor j

1. Introduction

The world's population resides in urban areas, growing from 30% in 1950 to 54% in 2014, and is projected to increase to 66% by 2050 (UN, 2018). This growth leads to a rapid increase in demand for housing, which many countries could not meet. Besides the population growth, the rapidly expanding population in the Kingdom of Saudi Arabia (KSA) is also caused by large movements of migrants, with a net inflow of more than 100 000 migrants per year in 2010–2015 (UN, 2017). This escalation puts pressure on the shortage of housing and the existing infrastructure in the KSA (Dudley, 2014). With an average annual population growth of 1.9%, by 2025, Saudi Arabia's population is projected to increase from 31 million (2015) up to 37 million. According to the Ministry of Housing, Saudi Arabia needs to provide 3.3 million units to meet the demand in 2025, which is about 300 000 units per year (Kerr, 2016). The Saudi construction industry could provide only 150 000 units per year using conventional construction methods (Kerr, 2016). An innovative approach to construction methods is needed to meet the demand gap for the housing shortage.

Implementing manufacturing methods to construction-related activities could improve quality while reducing project cost and

duration (Badir *et al.*, 2002; Blismas and Wakefield, 2009; Gibb and Isack, 2003; Shen *et al.*, 2009). Compared with the conventional construction method, this approach could reduce on-site construction labour by 9.5%, construction project duration by 20% and construction waste by 56% (Jaillon and Poon, 2009). It also improves construction quality and durability and cost savings for both project owners and construction contractors. As an approach in construction methods, off-site construction has been studied and implemented in some countries that experienced similar concerns (Badir *et al.*, 2002; Yashiro, 2014). However, there were differences in their development. They were dissimilar in their contexts; their histories concerning industrialised buildings have different origins and have followed different paths (Atkin, 2014). Therefore, this paper discusses a proposed framework for adopting off-site construction into the KSA construction industry. The paper begins with a brief literature review on off-site construction and its implementation, followed by a description of the research method. The results of the analysis and the discussion are presented next and followed by the conclusions.

2. Off-site construction

Off-site construction involves manufacturing and pre-assembling of building components, elements or modules before installation into their final location (Goodier and Gibb, 2007). It is an innovative approach to construction by implementing manufacturing methods in activities related to construction. It has some benefits compared with the traditional construction approach in improved productivity, reduced safety risks, enhanced sustainability, reduced on-site labour requirement, simplified training programme and reduced disruption to residents. This approach is growing in the construction industry under the name of modern method of construction (MMC) in the USA; prefabrication in Singapore and Hong Kong; and industrial

building system (IBS) in Sweden, Japan and Malaysia (Badir *et al.*, 2002; Blismas and Wakefield, 2009; Larsson *et al.*, 2014; Mao *et al.*, 2015; Rahman, 2014; Yashiro, 2014). Off-site construction starts in a factory as off-site production, which builds a prefabricated or precast component in modules or units. It continues with the delivery process from a factory to a construction site, and it ends with the installation of modules or units to complete building construction (Carr, 2015; Mao *et al.*, 2015).

Off-site construction can be subdivided into several categories based on increasing amounts of pre-assemblies (BCA, 2010; Gibb and Isack, 2003; Steinhardt *et al.*, 2014). The lowest level is the use of standard building materials, such as timber and bricks. The next level is using pre-cut or components assembled off-site – for example, trusses and doors. Next is the use of building elements that define space, such as a wall panel. Those three levels are considered non-volumetric assembly. The following three levels are defined as volumetric assembly. It starts with volumetric units that are added to existing structures/buildings, such as bathroom pods. Then, volumetric units are joined at the site to form part-houses/buildings. Finally, in complete pre-assembly, whole houses/buildings are completed off-site.

The implementation of off-site construction contributes to positive changes to construction projects. Earlier research studies show that project stakeholders who implement off-site construction method gain benefits such as improved productivity (Badir *et al.*, 2002; Baldwin *et al.*, 2009; Blismas and Wakefield, 2009; Hairstans, 2014; Jackson, 2013; Jaillon and Poon, 2010). Other benefits include reduced risks in safety (Haas, 2004; Jackson, 2013; Jaillon and Poon, 2008; Taylor, 2009), enhanced sustainability (Baldwin *et al.*, 2009; Gorgolewski, 2008; Hamid and Kamar, 2012; Shen *et al.*, 2009), less on-site labour requirement (Tam, 2002; Taylor, 2009), simplified training programme (Jackson, 2013) and less disruption to residents (Jaillon and Poon, 2008).

Although the benefits of implementing off-site construction have been recognised, this system has not been widely used (Larsson *et al.*, 2014; Rahman, 2014). In the UK, for example, the implementation of off-site construction is reported to be only 7% of the total construction (Carr, 2015). In the USA, as stated by Lu (2007), whom Rahman (2014) cites, factory-built housings represent only 20% of the residential sector, while housing projects that were built using MMCs were only 7%. The same condition also exists in China (Mao *et al.*, 2015).

Several barriers have been identified and studied as the reasons for low off-site construction implementation. Those barriers include lack of awareness and knowledge of off-site construction (Kamar *et al.*, 2009; Nawi *et al.*, 2015; Sadafi *et al.*, 2012; Yunus and Yang, 2014); resistance to change (Hairstans, 2014; Larsson *et al.*, 2014; Nawi *et al.*, 2015); the use of the design–bid–build project delivery system (Culmo, 2011; Kamar *et al.*, 2009; Larsson *et al.*, 2014; Simonsson, 2011); project owners focusing on the lowest bid (Blismas *et al.*, 2006; Gibb, 2001; Larsson *et al.*, 2014); stakeholders' perception that

off-site construction leads to rigidity and inflexibility in design (Larsson *et al.*, 2014; Lu and Liska, 2008), as well as inability to freeze design (Blismas *et al.*, 2005; Hairstans, 2014; Lu and Liska, 2008; Schofield *et al.*, 2009); technology dependency (Polat, 2010); manufacturing capacity of precast manufacturers (Schofield *et al.*, 2009); shortage of skilled labour (Badir *et al.*, 2002; Yashiro, 2014); restraint in transportation and process delivery (Lu and Liska, 2008; Nawi *et al.*, 2015; Schofield *et al.*, 2009; Taylor, 2009); and lack of guidelines and information (Hairstans, 2014).

Previous researchers have also identified factors that are considered enablers to improve the uptake of off-site construction. Those enablers include conducting comprehensive awareness programmes and exhibitions (Kamar *et al.*, 2009; Schofield *et al.*, 2009; Taylor, 2009); provision of comprehensive preliminary study in training, as well as skill training and courses for the university to set up young engineers and designers with deep understanding of off-site construction (Blismas and Wakefield, 2009; Kamar *et al.*, 2009; Lu and Liska, 2008); establishment of research and development (R&D) that focuses on off-site construction (Kamar *et al.*, 2009; Lu and Liska, 2008; Taylor, 2009); improved information technology adoption to support the integration of all activities in off-site construction process (Kamar *et al.*, 2009); improved communication and collaboration of the project owner, designer, contractor and manufacturer from the design and planning stage (Kamar *et al.*, 2009; Lu and Liska, 2008); direct government involvement in regulation, including developing standards and guidelines for design manufacturing and construction process (Nawi *et al.*, 2015; Taylor, 2009); and design innovations, which provide design options that can be easily modified and adjusted in the future (Sadafi *et al.*, 2012).

There is a lack of literature on the implementation of off-site construction in KSA. A report by Aburas (2011) was the only one that discussed this issue. His report indicated that off-site construction had been used in infrastructure and building projects by incorporating off-site construction. The use of off-site construction has been dominated by non-volumetric assembly, which is the use of off-site construction for only part of the building or structure (e.g. wall panels, half-slabs, precast columns and beams). Technical limitations, lack of supporting legislation and perceptions towards off-site construction were considered significant barriers in moving towards volumetric and modular construction. Some suggestions that resulted from the workshop included educating the construction industry stakeholders; incorporating more training and education programmes for construction professionals and university students, as well as the training of architects and designers in the philosophy of off-site construction; further growth in the manufacturing sectors; and government legislation that promotes the implementation of off-site construction.

Earlier research studies on off-site construction show benefits in implementing such a system. Its speed, which is associated with the construction process, could help a country with a rapid increase in housing demand, which Saudi Arabia currently faces.

Although off-site construction has been implemented in many countries, there were differences in their development. They were dissimilar in their contexts, their histories related to the industrialised building have different origins and they have followed different paths (Atkin, 2014). Therefore, there is a need to study the industrialisation of the building system in Saudi Arabia. Identifying the enablers for successfully adopting off-site construction is an important step. However, it cannot stop there. It is also essential to know how to adopt those enablers. Discovering the level or hierarchical structure and the interrelationships of those enablers can develop an in-depth understanding of the potential adoption of those enablers as a strategy in implementing off-site construction.

3. Research method

The research method used in this study included the following steps. Firstly, a literature review of off-site construction provided an understanding of the definition and concept of off-site construction, the factors that enable successful implementation and the barriers experienced by the construction industry in other countries in adopting off-site construction. Secondly, semi-structured interviews were conducted to identify the enablers of adopting off-site construction into the KSA construction industry. Thirdly, a questionnaire survey was conducted to verify the enablers for developing off-site construction in the KSA, distributed online to construction industry practitioners. Fourthly, a pairwise comparison survey was conducted among the initial interviewees to build a model using interpretive structural modelling.

The interview questions were developed based on the literature review, which was divided into three sections. The first section consists of questions on the respondents' backgrounds. The second section consists of questions related to current practices of adopting off-site construction in the KSA. Those questions include, for example, techniques used in the pre-assembly, which can help categorise the practices based on the increasing amounts of pre-assemblies, and the benefits of implementing off-site construction. The third section consists of enablers' questions on adopting off-site construction into the KSA construction industry. The interviews were conducted using semi-structured questions, which provided opportunities to explore responses further. The selected interviewees had at least 5 years of working experience in the KSA construction industry and had been implementing off-site construction in their projects. Thirteen out of the targeted 15 respondents were interviewed. They included two building owners, two engineering and design consultants, four building contractors, three precast companies and two academicians. The interviewees represented different KSA construction industry stakeholders to generate various opinions and perceptions and obtain broader views in implementing off-site construction. Instead of the interviewees' names, codes (e.g. i1, i2) were used to identify them.

Most of the interviews were conducted face to face, and several were conducted by phone or Skype. In the interviews, an audio recording was used to capture the responses of the respondents.

The audio recordings of the interviews were then transcribed. The transcriptions were analysed using qualitative analysis software, QSR International NVivo 11, to identify common, recurrent or emergent themes related to the current practices and enablers of adopting the industrialised building system.

The questionnaire survey was developed based on the results of the literature reviews and the interviews. The respondents were asked for their agreement on the enablers. A Likert scale, from 1 (strongly disagree) to 5 (strongly agree), was used to measure the respondents' agreement. The survey was written in two languages (English and Arabic), which were appropriate for the participants to understand the questionnaire clearly. Email invitations with a link to the survey web page were sent to 108 construction industry practitioners, including project owners, engineering and design consultants, building contractors, precast companies and academics.

The identified enablers may have overlaps and relationships that were sometimes difficult to see. A more comprehensive understanding of these factors and their relationships can be reached through a logical structure such as the interpretive structural model (ISM). ISM is a well-established methodology for identifying the hierarchy and relationships among specific items that define a problem or an issue (Sage, 1977; Warfield, 1974). A pairwise comparison survey was conducted to develop a model using ISM. The respondents for the pairwise survey were the interviewees from the interview stage of this research. The Delphi technique was used to generate consensus among the respondents. Additional respondents were invited to participate in this research to ensure a sufficient number of respondents for valid data gathering. A total of 14 agreed to participate in this survey. Rowe and Wright (1999) indicated that the size of a Delphi panel has ranged from as low as three to as high as 80. Hollowell and Gambatese (2010) suggested that the optimal number of panel members is 12–15, while Clayton (1997) suggested a panel consisting of 15–30 members. The number should be dictated by the characteristics of the study and the availability of experts. The panel size should also consider that some panellists may decide to drop out of the study due to other commitments (Hollowell and Gambatese, 2010). Therefore, the Delphi panel of 14 respondents was considered adequate.

4. Results

4.1 Interview results

The interview results revealed that the implementation of off-site construction in the KSA was limited to non-volumetric pre-assembly, predominantly used in structural concrete elements and building facades. All interviewees (i1–i13) confirmed that they had been implementing off-site construction for part of their buildings or structures such as wall panels, slabs, precast columns and beams and small-scale finishing works. Another category that applied only on limited projects is the volumetric type of pre-assembly. One interviewee (i6) had experience using that type, in

a university building project, for toilet pods. Three other respondents also mentioned in their interview that the modular type had been used limitedly in few major projects in several main cities in the KSA, although not directly experiencing this technique – for example, the use of modular components in hotel projects in Mecca and Jeddah (i11) and in a housing project for the Ministry of Interior in the Eastern Province (i13).

Based on the continuum of prefabrication construction methods described in the previous section, the current implementations of off-site construction in the KSA construction industry are still low. They are from level 1 up to level 3, which are considered non-volumetric frame building components. Non-volumetric with precast concrete has been used mostly for concrete structural elements or building components and building facades, which align with the effectiveness of off-site construction in a repetitive design nature. However, the study found that the perception of the off-site construction method in the KSA was positive. All participants agreed that the off-site construction approach improved project performances significantly in time and quality. There were also general agreements that off-site construction improved project productivity, solved the lack of skilled labour in the KSA and improved customer satisfaction. The findings were similar to previous research results regarding improved productivities, reduced project safety risks, enhanced sustainability, reduced on-site disruptions and reduced on-site labour requirements. This study showed some other benefits of implementing off-site construction, including encouraging new ideas, solving design issues and low maintenance costs.

From the interview results, eight factors were considered the enablers for the successful implementation of IBS in the KSA, as listed in Table 1. Two dominant factors were considered the main

Table 1. List of enablers for IBS implementation in KSA

Number	Enablers
1	Training and workshops of practitioners in the construction industry to improve their knowledge as well as skills related to IBS
2	Exhibitions, seminars and marketing campaigns to increase the awareness of construction project stakeholders of IBS
3	Having a system in a precast house that could easily be modified for future expansion without major changes with given design options to end users
4	Government's role in enabling the adoption of IBS in the government's housing projects
5	Improving and maintaining the transportation infrastructure, including the road conditions
6	Improving the communication system among construction project stakeholders from the design stage to the construction stage
7	Improving the capabilities of manufacturers (i.e. capacity and production process)
8	Having a pilot project as a sample of full implementation of IBS

enablers, which most respondents agreed on. They were training to improve stakeholders' knowledge on off-site construction (1) and exhibitions or campaigns to improve the people's awareness of off-site construction (2). Other enablers were having a system or flexible design on off-site construction projects (3), the government's role in enabling off-site construction in the government's housing projects (4), improving the transportation infrastructure (5), improving the communication system among stakeholders in the early stages of projects (6), improving the capability of manufacturers (7) and having a pilot project as a sample off-site construction project (8).

There are two main factors needed to overcome the lack of awareness and knowledge of IBS: education and awareness campaigns. All interviewees agreed that educating construction project stakeholders on IBS could improve their knowledge of and skills in adopting this system. This can be done by providing training and workshops to practitioners in the construction industry, including preparing engineers and designers for their university education. Some interviewees stated that 'we can utilize the university, use classes and show them this is the future of construction industry' (i6) and 'educating people is the only way to overcome this problem or increase the precast implementation as one of the techniques in IBS' (i8). One interviewee stated that 'the most important I can say is education. Conduct the training to all the people involved in the construction industry' (i7). Besides education, conducting exhibitions, seminars and marketing campaigns were identified by most respondents as ways to increase the awareness and knowledge of construction project stakeholders of IBS. As stated by some respondents, 'What should be done for me is the marketing issue. For the precast company, if they want other projects to use the IBS or, in this case, precast, they should present themselves more advanced, attractive or professional way' (i1) and 'increase the awareness campaign and increase the interaction of the manufacturer, the construction industry, and the people. For example, conduct the exhibition, introduce the IBS start in university bring the product and sample of the IBS project and so on' (i10).

In terms of design, having a system in a precast house that could easily be modified for future expansion without major change is also considered a significant enabler to implement IBS in the KSA. This can be done as stated by an interviewee from the manufacturer group: 'currently, many people still have much wrong understanding about IBS or precast. One of them is, they thought that by using precast, their house could not be extended in the future. This is wrong; in fact, the future modification is easier than the conventional method by using precast. We can modify anything. Because it is very easy to modify through the open joint, there are techniques to modify it. So, gaining the stakeholders' knowledge is the way to increase IBS implementation in the KSA' (i3).

The government has an essential role in enabling the adoption of IBS. Some respondents indicated that some government projects

had adopted precast construction. They believed that as the largest owner of housing projects, the government could lead the adoption of the IBS into the KSA construction industry. As mentioned by one interviewee (i2), ‘besides providing project the role of government is providing regulation, codes and guideline as needed since there is still lack of regulation in the implementation of IBS in KSA construction industry’.

Other enablers that were also mentioned by the respondents include improving the communication system among the stakeholders in the project from the design stage to the construction stage; improving and maintaining the transportation infrastructure, including the road conditions; improving the capabilities of manufacturers; and having a pilot project as a sample of full implementation of the IBS. Except having a pilot project as a sample of full implementation of IBS, those factors have also been identified in previous studies.

4.2 Survey results

The online survey questionnaire was conducted to verify the interview results on the barriers and enablers of implementing off-site construction in the KSA construction industry. Two additional enablers identified from the literature review were added to the eight enablers identified from the interview – namely, building regulations and standard guidelines on off-site construction techniques and government involvement, through incentives, to ensure finance and insurance.

The population of this survey was also the five main stakeholders of the KSA construction industry: project owners, engineering consultants, construction contractors, manufacturers and academics. The responses for each barrier and enabler were coded with numerical options from 1 to 5 with 1 indicating ‘strongly disagree’; 2, ‘disagree’; 3, ‘neutral’; 4, ‘agree’; and 5, ‘strongly agree’.

Fifty-three respondents responded to the online survey. Fifteen (28%) were project owners or developers, ten (19%) were designers or engineering consultants, 22 (41%) were construction contractors, four (8%) were precast manufacturers and two (4%) were academicians. Most of the respondents agreed with the ten enablers, which are indicated by median and mode scores of 4 and mean scores above 3.5.

4.3 Developing the ISM

In the pairwise questionnaire, the 14 respondents were asked to provide their opinions on the enablers’ relationships. The number of questions that the questionnaire contained was calculated using $N(N - 1)/2$, where N is the number of enablers between which the relationships would be investigated. Since there were ten enablers, the number of questions was $10(10 - 1)/2 = 45$. The respondents were asked to compare and complete 45 relationships by choosing a value from the set (V , A , X and O) to represent their perception of the relationship between two enablers at each time. The meanings of the V , A , X and O values are as follows:

Figure 1. Structural model of enablers for adopting off-site construction

- *V*: if factor *i* will help achieve factor *j*
- *A*: if factor *j* will help achieve factor *i*
- *X*: if factors *i* and *j* will help achieve each other
- *O*: if factors *i* and *j* will not help achieve each other or are unrelated.

To develop an ISM, one has to analyse first the contextual relationship of the related factors. This study used the contextual relationship of ‘will help achieve’, which indicates whether one factor will help achieve another. Based on this contextual relationship, a structural self-interaction matrix (SSIM) was then developed.

After obtaining the individual responses, the Delphi technique was used to generate consensus among the respondents. Two rounds were conducted in this survey. In the first round, the mode of each response was calculated. Mode values of 67% indicated strong agreement among all respondents. Out of 45 pairwise comparisons, 14 had mode values of above 67%. In the second round, the remaining comparisons indicating agreement of less than 67% were taken back to the respondents. The respondents were asked to reconsider their answers. After the second round, 11 pairwise comparisons had mode values of above 67% and 18 other pairwise comparisons had mode values between 50 and 67%. The majority of opinions were taken for the two remaining pairwise comparisons. Based on the respondents’ consensus, the SSIM was constructed. It was then transformed into a reachability matrix. From the final reachability matrix, the reachability set and antecedent set for each factor was found. The elements in the top level of the hierarchy will not reach any elements above their own level. As a result, the reachability set for a top-level element will consist of the element itself and any other elements within the same level which the element may reach, such as components of a strongly connected subset. Once the top-level enablers were identified, they were separated out from the other enablers. Then, the same process was repeated to find out the enablers in the next level. This process was continued until the level of each enabler was found. The resulting levels helped in building the digraph and the final model, shown in Figure 1.

5. Discussion

Level V in Figure 1 is the lowest level of the hierarchy. The lowest level illustrates that the level contains enablers that are the root of all the other enablers. The ISM suggests that the driving powers lie with the government’s role in enabling the adoption of off-site construction in governments (housing) projects; its involvement, through incentives, in ensuring finance and insurance; and establishment of building regulations and standard guidelines on the use of building techniques. As these three enablers have emerged as having the maximum driving power in the interpretive structural based model, they must be considered the root of the hierarchical structure of this model. The dominance of these enablers is logical. Through direct involvement as housing project owners and incentives to the private sectors, government’s involvement could provide a good foundation for

adopting off-site construction. Through the Ministry of Housing, the KSA government is the largest housing project owner in the Kingdom. The ministry announced the launch of four new housing projects in partnership with the private sector of 6499 housing units (MOH, 2018a). The Ministry of Housing has also launched the Building Technology Stimulus Program (MOH, 2018b), which aims to address the affordable housing demand gap by driving the adoption of innovative building technologies. The focus is on MMCs or off-site construction. These two enablers need to be complemented by establishing and providing regulations and standard guidelines on off-site techniques.

The following highest driving powers (level IV) are about increasing the awareness of construction project stakeholders of off-site construction, improving the knowledge and skills of construction industry practitioners on off-site construction through workshops and training and developing precast housing system units to be easily modified for future expansions. The lack of awareness and knowledge of off-site construction has been identified as the main barrier. Therefore, having enablers that could increase the awareness and knowledge of off-site construction at this level shows that they are critical in successfully adopting off-site construction. Parallel to those two enablers, it is also essential to establish R&D that focuses on off-site construction, which enables a system in a precast house that could easily be modified for future expansions without significant changes.

The next level of enablers (level III) is improving the communication system among construction project stakeholders. This could be effectively implemented when construction project stakeholders have better awareness and knowledge of off-site construction. This should be followed by improving manufacturers’ capabilities to meet future demand (level II). At the top level (level I), having a pilot project could provide a sample of full implementation of the off-site construction. The other enabler on the top level is to improve and maintain transportation infrastructure. This would enable the transportation of pre-assembled modules from manufacturing sites to construction sites without much restraint and process delivery issues.

6. Conclusions

This paper set out to understand the enablers for adopting off-site construction in the KSA construction industry and proposes a strategy or a framework to implement those enablers. Off-site construction could be implemented by considering the relationships and hierarchy of the enablers for adopting it.

The framework proposes that the government lead off-site construction adoption by providing incentives and establishing regulations and standard guidelines for using off-site construction techniques. This should be followed by increasing construction project stakeholders’ awareness and knowledge of off-site construction to develop buildings using this system, which could

be modified for future expansions without significant changes. The next step is to improve the communication system among construction project stakeholders from the design stage to the construction stage and improve manufacturers' capabilities. It is also essential to have a pilot project as a sample of full implementation of off-site construction and improve and maintain transportation infrastructures, including road conditions.

This paper has contributed to knowledge and understanding how to adopt off-site construction into the construction industry. The ISM model could be used to detail the hierarchy and the importance of each factor and provide a visual representation of the situation. The model is significant as it allows a practical framework for the relevant government authorities and other key stakeholders to focus on those factors that must be prioritised to establish successful adoption of off-site construction.

Although the fundamental arguments regarding the concepts and challenges of off-site construction in the construction industry remain consistent in this paper, the findings and views presented in the model reflect developing countries' situations since different countries must deal with different characteristics in their respective construction industries. Nevertheless, this model can serve as a guide for adopting off-site construction into the construction industry.

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