Development of implementation strategies for offsite construction techniques in the Kingdom of Saudi Arabia

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Abstract: Offsite construction is considered as a new method of building in Saudi Arabia in comparison to other countries. The aim of this research was to examine the main factors affecting offsite construction in Saudi Arabia in order to propose a feasible strategy for its wider implementation. To achieve the research aim, the researcher adopted a mixed method approach, combining semi-structured interviews and questionnaires. This paper presents the findings from the survey; the interview findings will be discussed in another publication. The questionnaire survey revealed that an increase in labour productivity and product quality as well as an overall reduction in project schedule are the main benefits of offsite construction. However, there are many challenges facing offsite construction in Saudi Arabia, including inflexibility in making on-site changes, limited design options, associated costs and risks, low awareness and resistance to offsite construction techniques (OCT).

Keywords: offsite construction techniques; OCT; construction industry; Kingdom of Saudi Arabia.

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1 Introduction

The rationale informing this research stems from the Saudi construction industry's acute managerial problems, which include planning inefficiency, low productivity, and cycles of mistakes and rework (MOP, 1997; Al-Saqer, 2001). In many previous studies, schedules and delays have been identified as a major and costly problem (Assaf et al., 1995; Assaf and Al-Hejji, 2006; Al-Kharashi and Skitmore, 2009). The benefits of offsite construction techniques (OCT) have been widely studied and include reductions in time, defects, health and safety risks, environmental impact, and whole-life cost, with a consequent increase in predictability, productivity, whole-life performance and profitability (see e.g., Gibb and Isack, 2003; Pan et al., 2007; Tam et al., 2007; Eastman et al., 2008; Arif, 2009). Many researchers believe that, in the context of innovative digital technology, OCT technology is the 'future of the construction industry' (Hampson and Brandon, 2004; Tam et al., 2007). Another study concludes that, in the Kingdom of Saudi Arabia, offsite construction is a relatively new area of research that has the potential to offer a solution to the construction industry, especially within the housing sector (Aburas, 2011).

Therefore, the aim of this research was to develop implementation strategies for OCT in the Kingdom of Saudi Arabia. The exploratory study sets out to answer the research questions and examine the hypotheses in order to develop an offsite construction strategy. The following were the main research questions of this study:

1 What are the factors and techniques affecting and enhancing offsite construction in the developed world?

2 What are the factors and techniques affecting and enhancing offsite construction in Saudi Arabia?

3 What main factors will contribute to a successful offsite construction implementation strategy in Saudi Arabia?

2 Literature review

OCT techniques such as prefabrication and modular construction are utilised in all types of development and could address many industry-wide challenges, including deficiency of skilled workers, tight project plans, as well as health and safety related issues. The utilisation of OCT is growing both in developed and developing countries. In the UK, the size of offsite construction industry grew from £2.2 billion in 2004 to £6 billion in 2006 (Gibb, 2007; Goodier and Gibb, 2007). But Pan et al. (2007) highlighted significant barriers against the use of OCT through their survey of the UK's leading house builders concluding that OCT requires higher capital cost and complex interfacing between offsite and on-site components and systems. Within the context of Malaysian construction industry, the Construction Industry Master Plan 2006–2015 has given significant importance to the use of industrialised building system (IBS), a term used for OCT systems (Kamar et al., 2010).

Likewise, the Australian construction industry has identified offsite manufacturing as a key vision for improving the industry (Blismas and Wakefield, 2009; Khalfan and Maqsood, 2014). The construction industry in Australia contributes over $200 billion to the economy and represents 7.5% of GDP. It is estimated that even a small productivity increase of 0.3% through OCT would result in increased GDP of $6.6 billion (Chandler, 2014). But according to Kanjanabootra et al. (2012) and Dalton et al. (2013), non-residential sector has seen the utilisation of OCT but not much was done in the residential sector.

On the other hand, Boyd et al. (2013) reported in detail the major drivers and barriers within the Australian context and showed the current uptake of the OCT in low rise apartment building construction using an innovative technology called the unitised building (UB) approach. Compare to the OCT utilisation in Australia, New Zealand (NZ) has a fast uptake of the OCT, as highlighted by PrefabNZ (http://www.prefabnz.com/). This BRANZ (2013) report highlights the benefits, drivers, and barriers of using OCT with many examples from around the country, both residential and commercial.

In order to increase the uptake of sustainable practices in China, OCT has been repeatedly promoted as a potentially viable alternative (Zhai et al., 2014). The construction sector in China accounts for about 6.5% of the total GDP, employing about 42 million people in 71,863 construction-related enterprises (Zhai et al., 2014). Jaillon et al. (2009) have identified that, for Hong Kong, the waste reduction benefit from adopting OCT is 52%. Tam et al. (2007) concluded that although there are many hindrances to OCT in Hong Kong, skilled supervision can lead to achieving better environment and quality of the final product. Arif and Egbu (2010) identified the challenge related to cultural change within the Chinese construction industry where on-site construction has been practiced for many decades. They suggested that, through education and motivation, one would be able to bring this change within the industry to move to OCT.

3 Research methods

This study employed mixed methods for collecting the primary data; quantitative data collection method was employed to give it statistical significance and qualitative data collection method was to provide contextual depth and establish reliability and validity. The quantitative data was collected through the use of questionnaires to determine the functional factors affecting offsite construction, and the qualitative data was collected through interviews, in order to achieve greater in-depth knowledge regarding the attitudinal factors affecting offsite construction in Saudi Arabia.

Table 1 Research methods

Objectives	*Research questions*	*Research methods*			
		Literature review	*Interviews*	*Questionnaire*	*ISM*
To describe and analyse the drivers and barriers regarding the use of OCT in the construction industry in a selection of developed countries and to extrapolate the sets of conditions which contribute to its success.	What are the factors and techniques affecting and enhancing OCT in the developed world?	S			
To investigate and analyse the barriers and drivers to the use OCT in the construction industry in Saudi Arabia.	What are the factors and techniques affecting and enhancing OCT in Saudi Arabia?	S	P	P	
To establish the relationships between the impact and the satisfaction among practitioners with the current implementations of OCT in Saudi Arabia.	What are the main factors that will contribute to a successful OCT implementation strategy in Saudi Arabia?	S	P	P	
To conceptualise a strategy (or strategies) for the successful implementation of OCT in Saudi Arabia.		S	P	P	P
To validate an implementation strategy and adoption process.				P	

Notes: S = secondary data, P = primary data.

There are several advantages of adopting a mixed method approach. According to Tashakkori and Teddlie (2003), mixed method answers the research questions more comprehensively and allows the researcher better to evaluate the extent to which the research findings can be trusted. Collecting quantitative data enhances interpretations by helping researchers better to contextualise qualitative findings. Quantitative research generates factual, reliable data that are usually generalisable to some larger population because of the large sample sizes, while qualitative research produces rich, detailed and valid process data based on the participants', rather than the investigator's, perspectives and interpretations.

The targeted population in this study were professionals involved in the construction sector (e.g., engineers, architects, project managers, academics and contractors). Following a mixed method approach, the participants responded through questionnaires and semi-structured interviews. The questionnaire was sent to 174 participants and 136 responded by completing it. Semi-structured interviews were carried out using a sample of six experts in the construction industry. Further to the use of both of these methods of data collection, the researcher conducted a focus-group interview, using interpretive structural modelling (ISM) to validate the results with four experts in the field of offsite construction. The details of the focus group have been discussed elsewhere. Table 1 shows the data collection methods used to respond to the research questions asked in this research.

4 Analysis of results

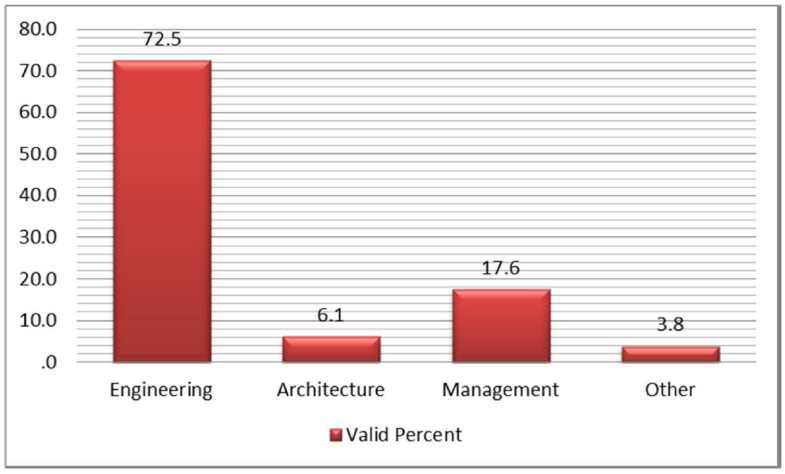
The aim of this research was to establish a means of ensuring that offsite construction in Saudi Arabia is both valid and achievable. This section will:

1 analyse data generated from questionnaires to investigate the feasibility of implementing OCT in Saudi Arabia

2 explore the possible advantages of their application and the ways in which they might be used

3 discuss potential reasons for their use and the challenges they present in a Saudi Arabian context.

Figure 1 Professional background of respondents (see online version for colours)



4.1 Descriptive analysis of the questionnaire

4.1.1 Personal and organisational background

Figure 1 demonstrates the professional background of respondents: the majority (72.5%) studied engineering; 17.6% studied management; 6.1% studied architecture; 3.8% highlighted other fields of study (or were contractors).

Figure 2 Educational qualification of respondents (see online version for colours)

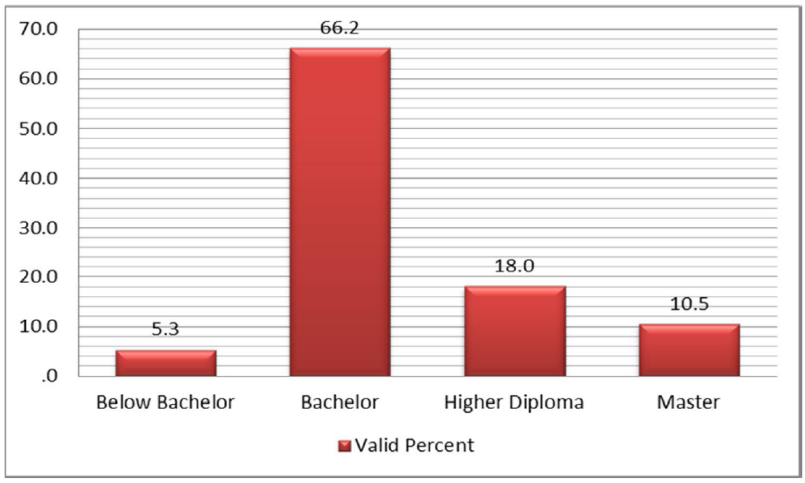
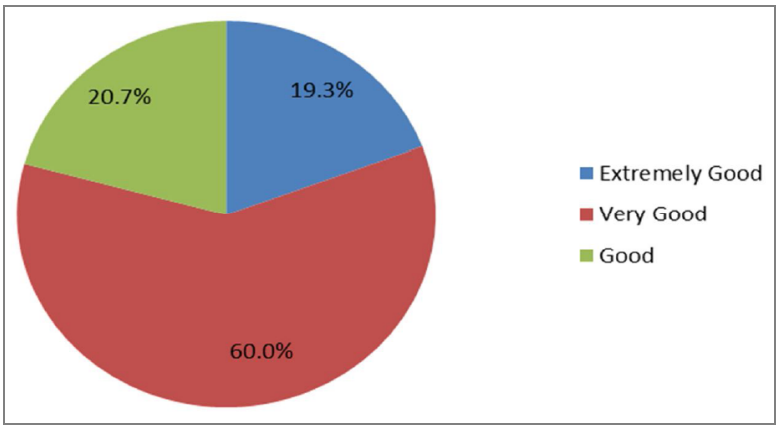


Figure 3 Communication levels with fellow workers (see online version for colours)



The most frequently observed educational qualification level among the questionnaire participants consisted of a bachelor's degree (66.2%) followed by a higher diploma (18%), and a master's (10.5%). 5.3% stated that they held a qualification below a bachelor's degree (see Figure 2).

Participants were invited to describe their level of communication with other colleagues (workers) during their construction and offsite construction work in Saudi Arabia. They were given a scale between 1 and 5 (i.e., from 'very poor' to 'very good'). All participants indicated positive levels of communication with their colleagues. The majority (60%) stated that their level of communication with other workers was very good; 20.7% stated that communication was good; 19.3% stated an extremely good level of communication (see Figure 3).

The level of the respondent's experience was varied (see Figure 4), with almost half (47.1%) having less than 5 years' experience; 24.3% having 5–10 years' experience; 11.8% having between 11–15 years' experience; 7.4% having 16–20 years' experience; 9.6% having over 20 years' experience.

Figure 4 Participants' experience of offsite construction in percentages (see online version for colours)

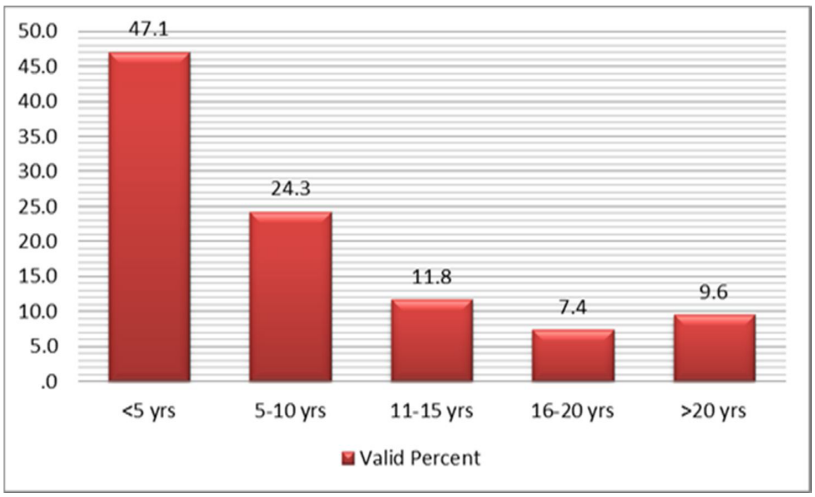
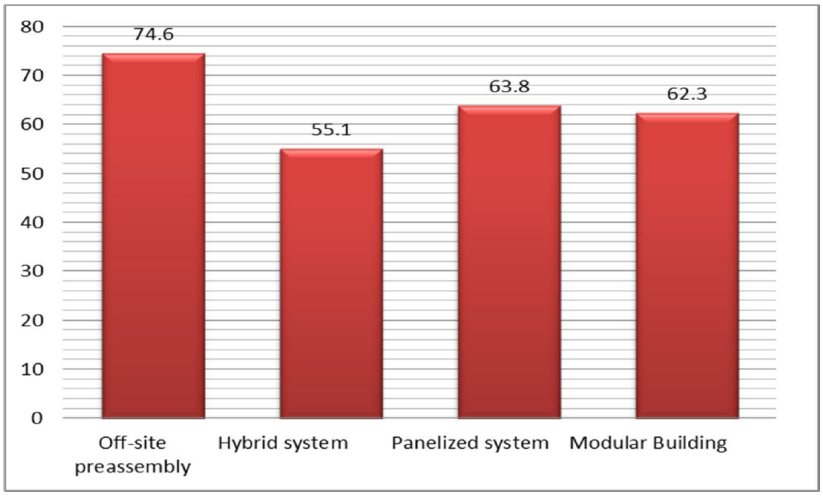


Figure 5 The offsite techniques used by participants (see online version for colours)

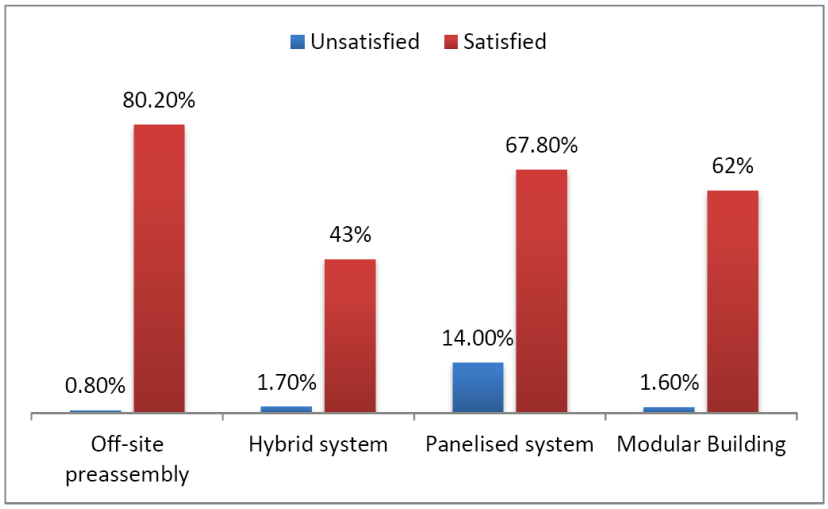


5 The techniques of offsite construction and satisfaction

This section describes the techniques of offsite construction and the satisfaction of participants regarding these techniques. The first section required participants to rate the

frequency of the four OCT (e.g., offsite preassembly; hybrid system; panelised system; modular building) from 1 = most used, to 4 = least used. An analysis of the responses revealed that 74.6% of participants used offsite preassembly; 63.8% used panelised systems; 37.7% used modular building; 55.1% used the hybrid system (see Figure 5).

Figure 6 The participants' level of satisfaction with the use of each of the OCT (see online version for colours)



The satisfaction of participants concerning OCT was rated on a five-point Likert-scale (i.e., 1 = very dissatisfied; 2 = dissatisfied; 3 = neutral; 4 = satisfied; 5 = very satisfied). Figure 6 demonstrates the use of each OCT option, along with the participants' level of satisfaction with their use. It was established that offsite preassembly demonstrated the highest satisfaction (80.2%); followed by:

1 the panelised system (67.8%)

2 the modular building (62%)

3 the hybrid system (43%).

6 Factors affecting OCT

This section of the analysis of the questionnaire concerns with an assessment of the effects of OCT in general. Participants were presented with 19 possible factors in relation to OCT, and asked to rate their levels of agreement or disagreement according to a five-point Likert-scale. Table 2 shows all 19 items ranked based on agreement and disagreement percentages.

6.1 List of factors and their rankings

One of the main objectives of the current study was to identify the primary factors affecting offsite construction in Saudi Arabia. The researchers focused on the most and

least influential factors. Table 2 includes all factors ranked from 1 to 19, based on the agreement percentages generated by the total number of participants.

Table 2 The ranking of the factors affecting the application of OCT in Saudi Arabia

Rank	*Factors affecting offsite construction techniques*	*Disagreement*	*Agreement*
1	Offsite construction techniques increase overall labour productivity.	4%	79%
2	Offsite construction techniques increase product quality.	17%	78%
3	Offsite construction techniques reduce the overall project schedule.	14.5%	77.6%
4	Offsite construction techniques limit the ability to make changes to onsite work.	9%	75%
5	Offsite construction techniques reduce the need for more skilled craft workers onsite.	18%	74 %
6	Offsite-construction techniques increase sustainability.	7%	66%
7	Offsite construction techniques reduce onsite disruption of adjacent operations.	9%	65%
8	Transportation limitations (i.e., size constraints; transportation costs; impact on building structures) limit the use of offsite construction techniques.	8%	64%
9	Offsite construction techniques limit design options.	18%	63.5%
10	Offsite construction techniques increase safety performance.	13.6%	61%
11	The investor's negative perception of offsite construction techniques limits the use of such techniques.	11%	59%
12	Offsite construction techniques increase project design efficiency.	5%	58%
13	Offsite construction techniques decrease the overall project cost.	29%	51%
14	Offsite-construction techniques increase initial cost.	25%	50%
15	Using offsite construction requires high use of IT in a construction industry.	26%	44%
16	Offsite-construction techniques increase the complexity of maintenance.	44%	37%
17	Offsite-construction techniques reduce construction waste.	44.4%	30.1%
18	Offsite-construction techniques increase the market value of property.	46%	22%
19	Offsite-construction techniques lack available codes and standards.	55%	15%

The four highest ranked factors in terms of importance are:

1 'Offsite construction techniques increase overall labour productivity'. This generated the highest level of agreement among respondents (79%).

2 'Offsite construction techniques increase product quality' (78%).

3 'Offsite construction techniques reduce the overall project schedule' (77.6%).

4 'Offsite construction techniques limit the ability to change onsite work' (75%).

The four lowest ranked factors are:

1 'Offsite-construction techniques increase the complexity of maintenance' (37%)

2 'Offsite-construction techniques reduce construction waste' (30.1%)

3 'Offsite-construction techniques increase the market value of property' (22%)

4 'Offsite-construction techniques lack available codes and standards' (15%).

Table 2 summarises the ranking of the factors affecting the application of OCT.

Table 3 The most common reasons for the use of offsite techniques in Saudi Arabia

Reasons	*No*	*Yes*	*Rank*
To compensate for restricted working space onsite.	110	28	*5*
	79.7%	20.3%	
To compensate for a shortage of skilled craft workers.	111	27	*6*
	80.4%	19.6%	
To compensate for local weather conditions.	134	4	*11*
	97.1%	2.9%	
To increase overall labour productivity.	110	28	*5*
	79.7%	20.3%	
To reduce the duration of construction.	50	88	*1*
	36.2%	63.8%	
To reduce the overall project schedule.	87	51	*3*
	63.0%	37.0%	
To reduce overall project cost.	74	64	*2*
	53.6%	46.4%	
To increase product quality.	97	41	*4*
	70.3%	29.7%	
To reduce design duration.	110	28	*5*
	79.7%	20.3%	
Project owners demanding the use of offsite construction techniques.	131	7	*9*
	94.9%	5.1%	
To reduce the environmental impact.	133	5	*10*
	96.4%	3.6%	
To improve project safety performance.	134	4	*11*
	97.1%	2.9%	
To increase a company's profit margin.	128	10	*7*
	92.8%	7.2%	
To enhance a company's reputation.	129	9	*8*
	93.5%	6.5%	
Any other reason:	136	2	*12*
	98.6%	1.4%	

7 Reasons for using offsite construction techniques

One of the main aims of this study was to examine the primary reasons for using offsite construction in Saudi Arabia. Participants were therefore asked to choose the top three most influential reasons for the use of offsite construction in Saudi Arabia from a choice of 15. Table 3 demonstrates the percentage and the frequency of the participants' answers.

1 The majority of participants (63.8%) agreed that the principal reason for the use of offsite techniques is that it helps 'to reduce construction duration'.

2 46.4% of participants agreed that offsite construction contains the capacity 'to reduce overall project costs'.

3 37% of the participants believed that it helps 'to reduce the project's overall schedule'.

Table 4 The level of agreement with challenges for the use of OCT in Saudi Arabia

Challenges	*No*	*Yes*	*Rank*
Designing offsite construction components requires specialised computer software.	90	48	*2*
	65.2%	34.8%	
Limited design options of using offsite construction techniques.	87	51	*1*
	63.0%	37.0%	
Local zoning ordinance restricts the use of offsite construction techniques.	130	8	*11*
	94.2%	5.8%	
Local building regulations restrict the use of offsite construction techniques.	115	23	*7*
	83.3%	16.7%	
Financial institutions restrict the use of offsite construction techniques.	119	19	*10*
	86.2%	13.8%	
Project owners do not allow the use of offsite construction techniques.	117	21	*8*
	84.8%	15.2%	
Lack of local skilled assembly craft works.	103	35	*5*
	74.6%	25.4%	
Use of offsite construction techniques will increase design costs.	101	37	*4*
	73.2%	26.8%	
Using offsite construction techniques will increase construction costs.	96	42	*3*
	69.6%	30.4%	
Transportation restraints.	118	20	*9*
	85.5%	14.5%	
General contractors do not have expertise in assembling prefabricated building components onsite.	106	32	*6*
	76.8%	23.2%	
Inability to make changes in the field using offsite construction techniques.	87	51	*1*
	63.0%	37.0%	

8 Challenges to use OCT

The researchers also established the challenges facing offsite construction in Saudi Arabia. In order to achieve this, the questionnaire listed 12 challenges, with participants being required to indicate the challenges they believed to be relevant to Saudi Arabian context. All participants were asked to identify three main challenges. Table 4 reveals the frequency and the percentage of participants agreeing with each of the 12 proposed challenges.

Based on the percentages, two challenge statements received the same level of agreement (i.e., the number of ticks).

1 37% of the participants agreed equally with the statements "Limited design options of using offsite construction techniques" and "there is an inability to make changes in the field when using offsite construction techniques".

2 35% of the participants agreed that the designing offsite construction firms 'requires specialised computer software'.

3 30% of participants agreed that, "using offsite construction techniques will increase construction costs".

9 Discussion and summary

The main aim of this research was to examine the development of a strategy for the implementation of offsite construction in Saudi Arabia. In order to achieve this outcome, it was vital to first study the current use of offsite construction in the country, while studying its advantages, disadvantages, and participants' satisfaction with the techniques, along with and possible barriers hindering the use of offsite construction and its techniques. This research focuses on four OCT (i.e., offsite preassembly; hybrid system; panelised system; and modular building) as independent variables, along with 19 factors related to offsite construction (i.e., dependent factors) identified as a result of the extensive literature review. The previous section summarised and described the effect of OCT using the 19 identified factors. Furthermore, such factors were correlated with the satisfaction of participants in relation to the OCT. This led to the predetermined hypotheses being answered, leading to the acceptance of some and the rejection of others.

The study was conducted amongst 136 participants from different backgrounds. It was established that all four OCT were employed, although the most frequently used technique was found to be offsite preassembly, closely followed by the remainder of the techniques. It was highlighted that offsite construction requires an increased number of skilled workers in comparison to traditional methods, and, while it leads to improved quality, it was demonstrated to:

1 shorten the project schedule

2 enhance safety and performance

3 decrease onsite disruptions

4 increase productivity.

It was demonstrated that the primary barrier is the complexity offsite projects. The need for support from planning and code departments was also highlighted. Further barriers include the inflexibility of offsite construction, (although it was also established that there is reduction in errors). A final barrier is the lack of appropriate transportation that hinders the completion of such projects. The adoption of offsite construction requires sufficient budget, time, design and flexibility. It was noted that such resources are required to be in place in order to fully adopt offsite construction.

Table 5 provides the summary by identifying the list of reasons for use of the OCT as well concludes as a list the challenges within the Saudi Arabian construction industry context.

Table 5 Summary of the reasons and challenges for the use of OCT in Saudi Arabia

Offsite construction (OCT)			
Reason to use OCT		*Challenge of using OCT*	
1	To reduce the duration of construction.	1	Inability to make changes in the field using offsite construction techniques.
2	To reduce overall project cost.		
3	To reduce the overall project schedule.	2	Limited design options of using offsite construction techniques.
4	To increase product quality.		
5	To reduce design duration.	3	Designing offsite construction components requires specialised computer software.
6	To increase overall labour productivity.	4	Using offsite construction techniques will increase construction costs.
7	To compensate for restricted working space onsite.	5	Use of offsite construction techniques will increase design costs.
8	To compensate for a shortage of skilled craft workers.	6	Lack of local skilled assembly craft works.
		7	General contractors do not have expertise in assembling prefabricated building components onsite.
9	To increase a company's profit margin.		
10	To enhance a company's reputation.	8	Local building regulations restrict the use of offsite construction techniques.
11	Project owners demanding the use of offsite construction techniques.	9	Project owners do not allow the use of offsite construction techniques.
12	To reduce the environmental impact.	10	Transportation restraints.
13	To compensate for local weather conditions.	11	Financial institutions restrict the use of offsite construction techniques.
14	To improve project safety performance.	12	Local zoning ordinance restricts the use of offsite construction techniques.

10 Contribution of this study to practice and knowledge

The construction sector in Saudi Arabia is constantly developing, and it still under researched. The contribution of this study is significant, as it is considered the first of its kind to be conducted in Saudi Arabia, looking at OCT and examining its impact, the reasons for its use and the barriers it may face. Using questionnaires survey and interviews as well as a focus group, this study has reached a conclusion with regard to the

main factors associated with the implementation of OCT. This paper only presents findings from the questionnaire survey. A number of benefits were associated with OCT: its quality, reduced time and schedule, need for fewer skilled workers and sustainability. Equally, the reasons for adopting OCT were also similar, highlighting duration/time and schedule followed by lower costs, better quality and higher productivity but, when examining the barriers, it was evident that OCT's inflexibility, the limited design options, the high cost, and the design costs were of great importance. However, it was clearly highlighted that the lack of risk taking and low awareness are factors that hinder OCT adoption, leading to resistance towards it.

This research has led to a better understating of OCT, and clarified the main factors that the government, companies, educators and policy makers should take into consideration in order to improve OCT in Saudi Arabia. Equally, this research has provided a solid platform for future research that could aim to expand knowledge in this field.

11 Recommendations

Based on the literature review and the research findings, this study proposes a number of recommendations that can improve OCT in the context of Saudi Arabia, and perhaps lead to improvements to the construction industry in general. Steps towards increasing the awareness of OCT will certainly help in using OCT to a greater extent, especially when targeting the agents (people) involved in construction. They are listed below here:

- A general awareness about OCT is crucial to its successful adoption. There is an urgent need to provide training methods aiming to improve awareness of OCT among manufacturers, architects, engineers, designers and local planning and building personnel. Increased awareness is essential, because only through that can OCT become more accepted in Saudi Arabia with less resistance.
- Saudi universities and technical colleges should teach students (engineers, architects, etc.) about utilising OCT in Saudi Arabia and also about the potential challenges and benefits related to its usage. This will create a new generation of innovative workers who are more likely to experiment with OCT and push the boundaries.
- Manufacturers, contractors, designers, engineers and architects should cooperate in order to increase and maximise the design options for OCT. This would improve OCT's flexibility, and lower the design costs. Clearly, inflexibility, the limited design options and high costs are barriers to this, according to this research.
- Positive, effective communication between workers and their superiors is also essential, as recommended by Pan et al. (2007). When referring to the social housing sector and the construction sector; they pointed out that sharing knowledge and communication as well as collaboration leads to success in construction. The members of a project (architects, developers, contractors and sub-contractors) should collaborate and take decisions together to introduce significant and innovative changes in the construction sector, especially OCT. Clear communication between teams and workers should always be enhanced to improve OCT implementation. Problem solving in the construction sector is best achieved through positive

communication between all of the individuals involved, from the top management and owners to the workers.

- There is also a need to train workers and improve their skills; only then can manufacturers see better productivity and fewer errors. There is also a need to improve the workers' computer skills, which are essential in OCT.
- Construction firms should be encouraged to take calculated risks with OCT, as it is generally considered risky, leading to it being used less. Many financial institutions may avoid financing OCT projects due to the unknowns; the calculated risks that they take will only improve OCT use.
- Special attention should be paid, in the process of innovation, to sub-contractors who fabricate, manufacture and buy products. They could influence the way in which OCT is designed and implemented.
- The Saudi government should be more committed to the construction industry and encourage OCT, since the government is considered a major player in promoting new ideas and plans in construction (e.g., with regard to regulations and codes).
- There needs to be a balance between the cost, value and quality of OCT projects and products. This will give clients or companies more reasons to consider the use of OCT.
- There is a need for experienced members of staff who will improve the confidence of other workers and ultimately the productivity level.
- There is a need to avoid high turnover in the construction sector in general, specifically OCT. Workers should be rewarded (in wages) and companies need to avoid losing skilful workers. Companies should avoid cheap unskilled labour.
- There is a need to encourage Saudi nationals to work in the construction industry in general and in OCT in particular. The employment of Saudis is avoided, at times, because of the availability of cheaper foreign labour; the government also needs to address this.

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