Use of offsite construction techniques in Pakistan

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Abstract: This study examines the benefits and challenges of offsite construction techniques (OCT) in Pakistani construction industry. It presents the view of consultants and contractors regarding offsite construction techniques by conducting a questionnaire survey. This study concludes that duration compression is the single most important factor that is driving the use of OCT in Pakistan. Moreover, the possible benefits of OCT include decrease in project duration; decreased need for skilled workers; increase in labour productivity; increase in site safety; increased design and management efficiency; and overall savings in cost. On the other hand, poor transportation facilities and logistics, and limited design options are challenges of offsite construction in Pakistani context. This study additionally analysed statistically the relationship between consultants and contractors in residential, commercial, infrastructure and industrial sectors for offsite construction techniques. A case study is also presented in this paper to compare the duration and cost of traditional onsite construction verses offsite construction.

Keywords: offsite construction techniques; OCT; Pakistani construction industry; Pakistan.

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1 Introduction

In offsite construction techniques (OCT), the prefabricated and standardised components/modules are manufactured in a controlled factory environment (either on- or off-site), transported, erected, and assembled into the on-site structure. OCT requires rethinking about the entire project development process, in order to take full advantage of both on- and off-site activities being managed concurrently (Khalfan et al., 2001). Construction industry players in many countries started to think about innovative ways of construction by integrating the off-site production with the on-site activities. This has resulted into decreased project construction time as the modules and prefabricated units are manufactured in parallel with the site works. Site disruption is also reduced due to less work on construction site (Barlow, 1999). The major advantage offered by offsite construction is in the form of worker safety and convenience in high rise building works. This technique is also feasible in places where site labour is expensive. Higher sustainability levels can also be achieved due to the controlled manufacturing environment. Waste management and safety management can also be improved through OCT (Lu and Liska, 2008). More specific drivers for the use of OCT are considered to be addressing traditional construction skill shortages, ensuring time and cost certainty and achieving high quality (Arif and Egbu, 2010; Boyd et al., 2013).

Prefabrication and modular construction is utilised to some degree in all types of development. Modularisation can possibly address numerous industry-wide challenges, including deficiency of skilled workers, tight project plans, as well as health and safety related issues. Due to the highlighted benefits, the utilisation of OCT is growing throughout the world, both I 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). Pan et al. (2007) identified significant barriers against the use of OCT through their survey of the UK's leading house builders. They concluded that OCT was perceived to be requiring higher capital cost and complex interfacing between off-site and on-site components and systems. The nature of design development process, the risk-averse culture, fragmented industry structure, manufacturing capacity, the local government planning system and concerns of mortgage lenders, and insurers with non-traditional buildings were also considered hindering the effective uptake of

OCT within the UK housing industry. Most of the above barriers were also identified in many other studies conducted in various countries.

The Construction Industry Master Plan 2006–2015 in Malaysia has given significant importance to the OCT. The term used is industrialised building system (IBS) and is defined as a construction technique in which components are manufactured in a controlled environment (on- or off-site), transported, positioned, and assembled into an on-site structure with minimal additional site works (Kamar et al., 2010). Likewise, the Australian construction industry has identified off-site manufacturing as a key vision for improving the industry in the coming decade (Blismas and Wakefield, 2009). 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% would result in increased GDP of $6.6 billion (Chandler, 2014). Although, most of the above mentioned construction activities are done using traditional methods, Blismas (2007) reports the current uptake and future direction of OCT within Australia.

But according to Kanjanabootra et al. (2012), non-residential sector has seen the utilisation of OCT but not much was done in the residential sector in the last few years. This was confirmed by Dalton et al. (2013) in their study, concluding that there was no real prospect of systematic movement from on-site to off-site production within housing sector. Boyd et al. (2013) reported in detail the major drivers and barriers within the Australian context using literature search. The case study presented by the authors in their paper shows the current uptake of the OSM in low rise apartment building construction using an innovative technology called the unitised building (UB) approach, involving only a limited number of players. 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, commissioned by one of the partners of PrefabNZ, highlights the benefits, drivers, and barriers of using OCT with many examples from around the country, both residential and commercial. The report summaries that OCT provides more security in economic outcomes and better environmental outcomes compared to on-site construction in NZ.

In China, in order to increase the uptake of sustainable practices, 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%, which is a significant saving on the island struggling to find landfill sites. 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. Another study by Zhang and Skitmore (2012) focuses specially on adoption of OCT in the residential housing sector. The research presents lists of the benefits and hindrances of OCT implementation in China. They highlighted two major hurdles;

1 OCT is not a cost effective construction method in comparison to the traditional construction method

2 there are insufficient manufacturers of prefabricated construction components for OCT to be viable on any scale throughout the country.

Although, OCT has been introduced globally but not widely adopted in Pakistan. Therefore, investigating the advantages and challenges of OCT in Pakistan has made this research an important and landmark work in its field. The primary objective of this study was to investigate the benefits and challenges of offsite construction in Pakistan and the secondary objective was to find out the perceptions of consultants and contractors about offsite construction within residential, commercial, industrial and infrastructure sectors. The following objectives were investigated in this study:

- investigation of the benefits and challenges of offsite methods in Pakistan
- exploration of the consultants and contractors point of views about offsite development strategies in Pakistani construction industry
- investigation of the perception of consultants and contractors in residential, commercial, infrastructure and industrial construction sectors

3 Research methodology

The research approach for this study was quantitative in nature. Questionnaire survey was used as primary data collection tool whereas literature review was employed for secondary data collection. The survey research is developed within the positivist approach to social science and produces both qualitative and numerical results about the beliefs, opinions, characteristics, and past or present behaviour, expectations, and knowledge of respondents.

The research started with an extensive literature review to identify benefits and challenges of OCT in construction industry from other parts of the world. Two semi-structured questionnaires were developed for the survey; one for the consultants and the other one for the contractors in Pakistani construction industry. Pilot study was conducted to check the validity and reliability of questionnaires. A total of ten interviews were conducted with the industry experts for the verification purpose during the pilot study. The questionnaires were then revised in the light of experts' opinions and sent to 140 people; 70 (50%) consultants and 70 (50%) contractors.

The questionnaires comprise of two sections: the first section deals with the general information about respondent and the second section gathers information on benefits and challenges of offsite construction based on seven-point Likert scale where 1 = strongly disagree, 4 = neither agree nor disagree and 7 = strongly agree. A case study was also conducted as part of the research and presented briefly in this paper. The main purpose of the case study was to verify some of the key findings concluded from the questionnaire survey.

4 Analysis and findings

Data was gathered using the questionnaire survey for this research. Descriptive statistics were conducted using the gathered data. Hypothetical testing was also carried out to analyse the data. For examining hypothesis statements, T-tests and ANOVA were conducted in order to compare the means of the respondents with the average mean assumed as 'neutral' (4). The research is carried out at 95% confidence interval. Furthermore, Spearman's ranking correlation was also conducted in this research. Linear regression was also done to determine correlation between the perceptions of consultants and contractors. Minitab, MS Excel and SPSS computer software were used for analysis.

According to Pakistan Engineering Council (PEC), the contractor categories are explained in Table 1. Table 1 also presents the number of contractors participated from each category for this research. This shows the almost equal representation from each category.

Table 1 Contractor categories in Pakistan

Category	*Description*	*Number of participants (70)*	*Percentage*
CA	No limit of construction cost	9	12.8%
CB	Construction cost limit up to 3,000 million PKR	9	12.8%
C1	Construction cost limit up to 1,800 million PKR	9	12.8%
C2	Construction cost limit up to 800 million PKR	9	12.8%
C3	Construction cost limit up to 400 million PKR	9	12.8%
C4	Construction cost limit up to 150 million PKR	9	12.8%
C5	Construction cost limit up to 50 million PKR	8	11.4%
C6	Construction cost limit up to 20 million PKR	8	11.4%

Table 2 shows the percentages of participants (both contractors and consultants) for each industry sector in Pakistan.

Table 2 Background of contractor and consultants

Sector	*Percentage of contractor (70)*	*Percentage of consultants (70)*
Residential	22.9%	28.6%
Commercial	28.6%	28.6%
Industrial	17.1%	14.3%
Infrastructure	31.4%	28.6%

When asked about the use of OCT in Pakistan, both consultant and contractors responded as below (see Table 3):

Table 3 Current OCT usage in the construction industry

Percentage of OCT usage in the industry	*Response from contractor*	*Response from consultants*
Less than 5%	19.4%	11.1%
About 6–10%	22.20%	25%
Between 11–20%	25%	22.2%

Table 3 Current OCT usage in the construction industry (continued)

Percentage of OCT usage in the industry	*Response from contractor*	*Response from consultants*
Say 21–30%	13.9%	13.9%
Around 31–40%	11.7%	16.7%
Greater than 40%	8.3%	11.1%

When asked about the single most important factor, 48.7% consultants responded reduced duration, 28.2% responded reduced cost, 10.3% responded quality being the most important and 7.7% responded safety as the single most important factor that is currently driving the use of OCT within the industry. In the subgroup of contractors, about 56.8% responded that offsite construction reduces duration, 21.6% reported reduction in cost, 10.8% reported increase in quality, and 8.1% responded that workforce being the single most important factor that was driving the use of OCT. Both consultants and contractors agreed in majority that the duration compression is the most important factor of offsite construction.

According to the reported responses of both consultants and contractors, the possible benefits of offsite construction are

1 decrease in project duration
2 need for skilled workers
3 reduction in onsite congestion
4 negative impact of other operations
5 labour congestion in site
6 increase in labour productivity
7 increase in safety in construction site
8 increase in design efficiency
9 increase in management efficiency
10 overall savings in cost.

Further, the reported challenges are transportation feasibility and limited options for design. The Linear relationship between consultants and contractors responses was 90.9%. The spearman's ranking correlation was 0.999475.

The comparison of responses from participating contractors from identified categories are shown in Table 4. The spearman's correlation factor is 0.6843 for contractor's categories which shows 68.43% similarity of ranked responses among these categories on highlighted factors in Table 4. As each category of contractors have different offsite practices along with variation in planning strategies, design tools, options and software, etc., therefore, categories of contractor show difference in ranking of various factors such as project planning, complicated software for design, limited options for design as barriers for OCT implementation.