Use of offsite construction techniques in Pakistan

Article · January 2016

DOI: 10.1504/MEJM.2016.079745

3 authors, including:

Muhammad Jamaluddin Thaheem
Deakin University
74 PUBLICATIONS **243** CITATIONS

SEE PROFILE

Use of offsite construction techniques in Pakistan

Wajahat Sammer Ansari

Department of Civil Engineering,
Pakistan Institute of Engineering and Technology,
Southern Bypass, Multan, 60000, Pakistan
Email: wajahatsammeransari@yahoo.com

Muhammad Jamaluddin Thaheem

Department of Civil Engineering,
National University of Sciences and Technology,
Islamabad, Pakistan
Email: jamal.thaheem@nit.nust.edu.pk

Malik M.A. Khalfan*

Department of Civil Infrastructure and Environmental Engineering,
Khalifa University,
Abu Dhabi, UAE
Email: malik.khalfan@gmail.com
*Corresponding author

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.

Reference to this paper should be made as follows: Ansari, W.S., Thaheem, M.J. and Khalfan, M.M.A. (xxxx) 'Use of offsite construction techniques in Pakistan', *Middle East J. Management*, Vol. X, No. Y, pp.000–000.

Biographical notes: Wajahat Sammer Ansari is a Civil Engineer by training. Currently, he is working as a Lecturer in Civil Engineering Department at Pakistan Institute of Engineering and Technology, Multan, Pakistan for the last three years. He is one of the experts within the area of offsite construction in Pakistan.

Muhammad Jamaluddin Thaheem is working as an Assistant Professor of Construction Engineering and Management at NICE, National University of Sciences and Technology (NUST). He specialises is in the area of project risk management and supply chain management.

Malik M.A. Khalfan is an Associate Professor in Project Management and has several years of experience in teaching, research and consultancy in the areas of procurement and supply chain management, sustainable development, construction technology and knowledge management.

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.

Table 4 Responses from participating contractors

Hypothesis statement of questions	*CA*	*CB*	*C1*	*C2*	*C3*	*C4*	*C5*	*C6*
Limit changes in onsite work	×	✓	✓	✓	✓	✓	✓	✓
Reduces project duration	✓	✓	✓	✓	✓	✓	✓	✓
Reduces need of skilled labours	✓	✓	✓	✓	✓	✓	✓	✓
Reduces cost of construction project	×	✓	✓	✓	✓	×	×	✓
Increases quality of product	×	✓	×	✓	✓	✓	✓	✓
Increases productivity of labours	✓	✓	✓	✓	✓	✓	✓	✓
Limits option for design	×	✓	✓	✓	✓	×	×	×
Increases performance of safety	×	✓	×	✓	✓	✓	×	✓
Reduces disruption of other operations	✓	✓	✓	✓	✓	✓	✓	✓
Reduces negative impact of other works	✓	✓	✓	✓	✓	✓	✓	✓
Transport restrictions limit their uses	✓	✓	✓	✓	✓	✓	✓	✓
OCT increase project design efficiency	✓	✓	✓	✓	✓	✓	✓	✓
Cost of design increases	✓	✓	✓	✓	✓	✓	✓	×
Software's for designing offsite methods limit their uses	×	✓	✓	✓	✓	✓	×	×
Increases jobsite management efficiency	✓	✓	✓	✓	✓	✓	✓	✓
Decreases labour congestion	✓	✓	✓	✓	✓	✓	✓	✓
Cost savings increases	×	✓	✓	✓	×	×	×	✓
Labour savings increases	✓	✓	✓	✓	✓	✓	✓	✓
Planning is barrier for offsite methods	✓	×	×	×	×	✓	×	×

The comparison of responses from participating consultants from different sectors is shown in Table 5. The spearman's correlation factor is 0.982766, which suggests 98.27% similarity of ranked responses among participating consultant from different sectors. For example, consultant sectors show different ranking in decrease of labours and increase in jobsite management efficiency in offsite construction.

Table 5 Responses from participating consultants from different sectors

Hypothesis statement of questions	*Residential*	*Commercial*	*Industrial*	*Infrastructure*
Limit changes in onsite work	✓	✓	✓	✓
Reduces project duration	✓	✓	✓	✓
Reduces need of skilled labours	✓	×	×	×
Reduces cost of construction project	×	✓	✓	✓
Increases quality of product	✓	×	✓	✓
Increases productivity of labours	✓	✓	✓	✓
Limits option for design	✓	×	✓	✓
Increases performance of safety	✓	×	✓	✓
Reduces disruption of other operations	✓	✓	✓	✓
Reduces negative impact of other works	✓	✓	✓	✓
Transport restrictions limit their uses	✓	×	✓	✓

Table 5 Responses from participating consultants from different sectors (continued)

Hypothesis statement of questions	*Residential*	*Commercial*	*Industrial*	*Infrastructure*
OCT increase project design efficiency	✓	✓	✓	✓
Cost of design increases	✓	×	✓	✓
Software's for designing offsite methods limit their uses	×	×	✓	✓
Increases jobsite management efficiency	✓	×	✓	×
Decreases labour congestion	✓	✓	✓	✓
Cost savings increases	×	✓	✓	✓
Labour savings increases	✓	×	✓	✓
Planning is barrier for offsite methods	✓	✓	✓	×

The comparison of responses from all participating contractors from different sectors is shown in Table 6. The spearman's correlation factor is 0.947896, suggesting 94.78% similarity of ranked responses among contractors from various sectors. Major difference of ranked responses was observed due to constraints in project planning, changes in onsite work and availability of software for design.

Table 6 Responses from participating contractors from different sector

Hypothesis statement	*Residential*	*Commercial*	*Industrial*	*Infrastructure*
Limit changes in onsite work	✓	✓	✓	✓
Reduces project duration	✓	✓	✓	✓
Reduces need of skilled labours	✓	✓	✓	✓
Reduces cost of construction project	×	✓	×	✓
Increases quality of product	×	✓	✓	✓
Increases productivity of labours	✓	✓	✓	✓
Limits option for design	×	✓	✓	✓
Increases performance of safety	×	✓	✓	✓
Reduces disruption of other operations	✓	✓	✓	✓
Reduces negative impact of other works	✓	✓	✓	✓
Transport restrictions limit their uses	✓	✓	✓	✓
OCT increase project design efficiency	×	✓	✓	✓
Cost of design increases	×	✓	✓	✓
Software's for designing offsite methods limit their uses	×	✓	✓	×
Increases jobsite management efficiency	✓	✓	×	✓
Decreases labour congestion	✓	✓	✓	✓
Cost savings increases	✓	✓	✓	✓
Labour savings increases	✓	✓	✓	✓
Planning is barrier for offsite methods	✓	×	×	×

The last analysis that was carried out in this series was the comparison of responses from participating consultants and contractors from different sectors; listed as below:

- residential sector shows 20.9% linear relationship in responses and the value of spearman's correlation factor was 0.994454 between consultants and contractors
- commercial sector shows 0% linear relationship and the value of spearman's correlation factor was 0.995923 between consultants and contractors
- industrial sector shows 1.2% linear relationship in responses and the value of spearman's correlation factor was 0.997078 between consultants and contractors
- infrastructure sector shows 14.7% linear relationship and the value of spearman's correlation factor was 0.996676 between consultants and contractors.

5 Case study

A construction project was undertaken as a case study to compare the cost and duration of the project using offsite and onsite traditional construction approach by using cost estimation approach. The main purpose of the case study was to verify some of the key findings from the questionnaire survey. The project was situated in Multan. Multan is a city in Punjab, Pakistan. It is Pakistan's fifth biggest city by populace and has a territory of 133 square kilometres (51 sq mi). The project consists of four-floor frame structure building with minimum compressive strength of concrete of 3,000 psi and 3,750 psi in slabs, beams, columns and footing. The steel yield strength was 60,000 psi. The cement used in project was Portland cement. The water cement ratio of 0.4 was used. The initial setting time of cement was 45 minutes. The hanger bars of #4 at 12" C/C and the reinforcement in slabs and footings are of #4 bar at 6" c/c in both directions. The slab thickness was 5". The aggregate size for concrete was 1.5". The curing period was 12 days. The clear cover provided for slabs, columns, beams, lintels were 3/4", 1.5", 1.5" and 1".

The cost estimation of the project was done through both traditional onsite approach and offsite construction approach. The rates of materials were collected from local material market of Multan. Only precast beams and slabs were available in Multan, therefore, for offsite construction only beams and slabs were taken in account. After conducting the cost comparison between two approaches for the project, the finding was that cost of the offsite construction was 10.9% less than onsite traditional construction. The schedule comparison of project was done through traditional onsite and offsite construction approaches. By doing comparison of schedule, the traditional onsite construction and offsite (taking Precast Slab and Beams only) construction approaches duration were as follows (see Table 7):

Table 7 Schedule comparison of traditional onsite and offsite construction approaches

Onsite construction schedule total duration = 280 days	Offsite construction schedule total duration = 252 days	Difference in days = 280 days – 252 days = 28 days	Difference in % = (1 – 252 / 280) × 100 = 10%

Therefore, it was concluded that a project done using OCT takes 10% less time to complete than constructed through traditional onsite approach.

6 Discussion

From the findings presented above from the survey conducted with the construction contractors, researchers concluded that all of them agreed that it decreases project time duration, increases management efficiency on construction site, and decreases onsite labour effort and congestion. Majority of them also agreed that OCT reduces need for skilled workers and reduces overall project construction cost. None of the contractors disagree to the fact that OCT increases product quality and increases labour productivity.

On one hand, all of them agreed that OCT increases project design efficiency but at the same time it increases design cost. All contractors also agreed to the facts that transportation restrictions limit the uses of OCT. In addition to these barriers, half of them also highlighted that the use of complex computer software also limit the adoption of OCT. Limitation to introduce changes during on-site construction was also regarded as barrier to the adoption of OCT by most of the contractors.

There were mixed responses when contractors were asked about increased safety performance on site. Also only half of them agreed that OCT limits available design options. With this respect, using OCT for complex project was considered to be challenging. Construction consultants shared very similar point of view overall as shared by the contractors. The next few paragraphs present the discussion about the perception of both contractors and consultants from different sectors collectively towards the implementation of OCT in Pakistani construction industry.

All participants including consultants and contractors from all sectors agreed that it reduces duration of a project, reduces onsite disruption, and increases workers' productivity on construction site. All the consultants agreed except from commercial sector that OCT limits to make changes during on-site work. On the contrary, all contractors from commercial sector agreed that it limit changes during on-site work. This could be because of first hand experiences of these contractors on various construction sites in the past. There was mix perception regarding the need for reduced skilled work force on the construction site. None of the consultants agreed except the ones from residential sector that it reduces the need for skilled workers on-site. Whereas all contractors thought that it does decrease the need for skilled workers. The researchers were not able to bring everybody to agree about the reduction in cost when using OCT. Consultants from residential sector did not see any financial benefits of OCT approach, nor contractors from industrial sector see any cost advantages over traditional construction. All of them were in agreement that available transportation facilities both in terms of vehicles and infrastructure restrict the use of OCT.

Both consultants and contractors from commercial sectors were not convinced that OCT increases quality of the facility which they were building. On the other hand, both consultants and contractors from industrial sector were convinced that OCT increases safety on construction site. The responses from all the participants were in harmony when they were asked two questions; one about the design efficiency and second about the available design options. Everybody agreed to the fact that OCT brings design efficiency but complained that these design options are limited and could not design anything or everything. They were all happy to note that OCT does not result into increase in project design cost.

Whether OCT increases management efficiency, there were mixed responses across the board. Consultants from residential and industrial sector agreed whereas consultant from commercial sector disagreed. On the other hand, the contractors from commercial

and infrastructure sector agreed to the fact that OCT increases management efficiency on construction sites. There were two major concerns which everybody mentioned; one was to do with the fact that construction industry within Pakistan does not have many skilled personal who could deal with the complicated software used during design and manufacturing stage of OCT components. The second concern was related to the existing planning regulations, which was causing barriers towards the uptake of OCT in general in Pakistan.

7 Conclusions

OCT are used worldwide but only precast and prefabricated products are used in Pakistan. According to the responses of consultants and contractors, OCT has many benefits including decrease in project duration; reduction in onsite congestion; increase in labour productivity; increase in safety on construction site; increase in design and management efficiencies; less environmental impact; overall savings in cost; etc. But there are challenges which hamper these advantages, such as need for skilled workers, transportation feasibility, and limited options for design.

Findings also indicated that contractors in different categories identified have different perceptions about offsite construction, which were reflected through their responses during the questionnaire survey. There are also different perceptions of consultants and contractors in residential, commercial, infrastructure and industrial sectors about offsite construction. The study recommends that construction contractors and consultant should engage more in using OCT in Pakistani construction industry in order to achieve its highlighted benefits, as well as to overcome its challenges through further research and development activities.

References

Arif, M. and Egbu, C. (2010) 'Making a case for offsite construction in China', *Engineering, Construction and Architectural Management*, Vol. 17, No. 6, pp.536–548.

Barlow, J. (1999) 'From craft production to mass customization', *Housing Studies*, Vol. 14, No. 1, pp.23–42.

Blismas, N. and Wakefield, R. (2009) 'Drivers, constraints and the future of offsite manufacture in Australia', *Construction Innovation*, Vol. 9, No. 1, pp.72–83.

Blismas, N.G. (2007) *Off-Site Manufacture in Australia: Current State and Future Directions*, Cooperative Research Centre for Construction Innovation, Brisbane, Australia.

Boyd, N., Khalfan, M.M.A. and Maqsood, T. (2013) 'Off-site construction of apartment buildings', *Journal of Architectural Engineering*, Vol. 19, No. 1, pp.51–57.

BRANZ (2013) *Prefabrication Impacts in the New Zealand Construction Industry*, BRANZ Report, BRANZ.

Chandler, D. (2014) *A Case for an Australian Construction Strategy*, Commonwealth Government Productivity and Industry Discussion Paper [online] http://www.oalib.com/references/15080174 (accessed 14 July 2016).

Dalton, T., Hurley, J., Gharaie, E., Wakefield, R. and Horne, R. (2013) *Australian Suburban House Building: Industry Organisation, Practices and Constraints*, AHURI Final Report 213.

Gibb, A. (2007) *Offsite Construction Industry Survey – 2006*, Build Offsite, London, UK.

Goodier, C. and Gibb, A. (2007) 'Future opportunities for offsite in the UK', *Construction Management and Economics*, Vol. 25, No. 6, pp.585–595.

Jaillon, L., Poon, C.S. and Chiang, Y.H. (2009) 'Quantifying the waste reduction potential of using prefabrication in building construction in Hong Kong', *Waste Management*, Vol. 29, No. 1, pp.309–320.

Kamar, K.A.M., Abd. Hamid, Z., Ghani, M.K., Egbu, C. and Arif, M. (2010) 'Collaboration initiative on green construction and sustainability through industrialized buildings systems (IBS) in the Malaysian construction industry', *International Journal of Sustainable Construction Engineering and Technology*, Vol. 1, No. 1, pp.119–127.

Kanjanabootra, S., Wynn, M.T., Ouyang, C., Kenley, R. and Harfield, T. (2012) 'Re-use of domain knowledge to provide confidence for adoption of off-site manufacturing for construction in Australia', in Kashiwagi, D. and Sullivan, K. (Eds.): *Proceedings of the Construction, Building and Real Estate Conference*, Las Vegas, NV, USA, pp.1270–1277.

Khalfan, M.M.A., Anumba, C.J. and Carrillo, P.M. (2001) 'Development of a readiness assessment model for concurrent engineering in construction', *Benchmarking: An International Journal*, Vol. 8, No. 3, pp.223–239.

Lu, N. and Liska, R.W. (2008) 'Designers' and general contractors' perceptions of offsite construction techniques in the United State construction industry', *International Journal of Construction Education and Research*, Vol. 4, No. 3, pp.177–188.

Pan, W., Gibb, A.F. and Dainty, A.R.J. (2007) 'Perspective of UK house builders on the use of offsite modern methods of construction', *Construction Management and Economics*, Vol. 25, No. 2, pp.183–194.

Tam, V., Tam, C., Zeng, S. and Ng, W. (2007) 'Towards adoption of prefabrication in construction', *Building and Environment*, Vol. 42, No. 10, pp.3642–3654.

Zhai, X., Reed, R. and Mills, A. (2014) 'Factors impeding the offsite production of housing construction in China: an investigation of current practice', *Construction Management and Economics*, Vol. 32, Nos. 1–2, pp.40–52.

Zhang, X. and Skitmore, M. (2012) 'Industrialized housing in China: a coin with two sides', *International Journal of Strategic Property Management*, Vol. 16, No. 2, pp.143–157.