A STATISTICAL REVIEW OF OFFSITE CONSTRUCTION TECHNIQUES IN PAKISTAN

Wajahat Sammer Ansari, Zia ur Rehman*, Muhammad Jamaluddin Thaheem, Usama Khalid *****

Pakistan Institute of Engineering and Technology, 1.7 km Southern Bypass Multan, Pakistan

wajahatsammeransari@yahoo.com

* **Zia ur Rehman (Corresponding Author)**

Department of Civil Engineering, UCET, University of Sargodha, Pakistan

engr_ziaurrehman@yahoo.com

** Department of Civil Engineering, National University of Sciences and Technology, Islamabad, Pakistan

*** Department of Civil Engineering, CIIT, Sahiwal, Pakistan

ABSTRACT: *This study examines the benefits and challenges of offsite construction techniques in Pakistan construction industry. It discusses about the view of consultants and contractors about offsite construction techniques. This study indicate that duration compression is the single most important factor that is driving the use of offsite construction. Moreover, the possible benefits of such construction techniques include decrease in project duration, need for skilled workers, reduction in onsite congestion, and negative impact of other operations, labor congestion on site, increase in labor productivity, and increase in site safety, design efficiency, management efficiency and overall savings in cost. On the other hand, transportation feasibility and limited options for design are challenges in offsite construction. This study examines the comparative behavior of various categories for contractors as registered by national accreditation body (Pakistan Engineering Council - PEC). This study additionally finds a relationship between consultants and contractors in residential, commercial, infrastructure and industrial sectors about offsite construction techniques. Case study is also included to compare duration and cost of traditional onsite and offsite construction*.

KEYWORDS: Construction, labor, offsite, preassembly, construction, modular, panelized, Pakistan construction industry.

INTRODUCTION

Offsite construction is a type of construction in which structures are built at different locations than where they are assembled and erected [1]. Offsite construction has been utilized in projects since many years owing to its benefits such as cost control and quality improvement. However it faces its fair share of challenges as well in the form of transportation and supply chain limitation and lack of onsite customizability. Practically, the offsite construction consists of precast, prefabrication, modular and panelized construction. The offsite construction techniques decrease 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 [2]. 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 labor 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 offsite construction techniques [3]. Some of the potential benefits of offsite construction include increasing the efficiency and reducing the environmental impacts of structural steel construction process [4-13]. Offsite construction reduces operation duration and waste by enhancing safety performance and productivity rate[14-19]. Prefabrication and Modular construction is utilized to some degree in all types of development. The future applications of modular construction are required to increment at a quick pace because of utilization of BIM in projects. Modularization can possibly address numerous repeating industry difficulties, including deficiency of skilled workers, tight plans, a reduction in duration, and decrease in site hazards by decreasing onsite work. Non-availability of prefabrication units in site, restricted site layout, and modular design rigidity are the barriers for modular construction [20-24].

Offsite construction techniques are introduced in global industry but not widely adopted in Pakistan. Therefore, investigating the advantages and challenges of offsite methods in Pakistan has made this research an important and landmark work in its field.

.

RESEARCH OBJECTIVES

The primary objective of this study is to investigate the benefits and challenges of offsite construction in Pakistan and the secondary objective was to find perceptions of consultants and contractors about offsite construction and there sub group perceptions according to residential, commercial, industrial and infrastructure sectors. Further, the comparison of perception of contractors within their categories is also studied. The following objectives are investigated in this study:

. Investigation of the benefits and challenges of offsite methods
. Exploration of the consultants and contractors views about offsite development strategies in Pakistan development industry
. Investigation of perception of different categories of contractors as established by the national accreditation body (Pakistan Engineering Council)
. Investigation of the perception of consultants and contractors in residential, commercial, infrastructure and industrial construction sectors

METHODOLOGY

Study Procedures

The research started with an extensive literature survey to identify benefits and challenges of offsite construction techniques in construction industry. Two open-ended

questionnaires were developed; one for the consultants and the other for the contractors. Pilot study was conducted to check the validity and reliability of questionnaires. Total 10 interviews were taken from industry experts. The questionnaires were revised in the light of experts' opinions. The final sample numbered 140 with 70 (50%) consultants and 70 (50%) contractors.

Sampling

According to Koterlik [25] for population equal or greater than 4000 the required returned minimum sample size is 119 [26]. The number of consultants and contractors in Pakistan are surely above 4000; therefore, minimum sample size taken for this research should be greater than 119. Therefore, in case of this research 140 responses were collected, which is a representative sample.

Research Instrument

The questionnaires comprise of two sections: the first section deals with the general information about respondent and the next section gathers information on benefits and challenges of offsite construction based on 7 point Likert scale as explained in Table 1.

Research Analysis

Ordinal data was gathered for this research. Descriptive statistics were also made. Hypothetical testing was done to analyze 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.

FINDINGS

Information of Contractors PEC Categories

According to Pakistan Engineering Council (PEC) the contractor categories are explained in Table 2.

From the seventy (70) contractors, nine (9) were C-A, nine (9) were C-B, nine (9) were C-1, nine (9) were C-2, nine (9) were C3, nine (9) were C4, eight (8) were C5 and eight (8) were C6.

Information of Respondents Construction Sectors

From 70 consultants, 28.6% were from residential, 14.3 % from industrial, 28.6 % from commercial and 28.6 % from infrastructure. From 70 contractors, the 22.9% were from residential, 17.1% from industrial, 28.6% from commercial and 31.4% from infrastructure construction sectors.

Degree of Offsite Construction in Pakistan

The 11.1% consultants and 19.4% contractors responded that degree of offsite construction in Pakistan is less than 5%, 25% consultants and 22.20% contractors say that it is about 6-10%, 22.2% consultants and 25% contractors say 11-20%, 13.9% consultants and 13.9% contractors say 21-30%, 16.7% consultants and 11.7% contractors say 31-40% while 11.1% consultants and 8.3% contractors say that the degree of offsite construction is greater than 40% in Pakistan.

Single Most Important Factor

The 48.7% consultants responded that offsite construction reduces duration, 28.2% responded that it reduces cost, 10.3% responded quality and 7.7% responded safety as the single most important factor that is currently driving the use of offsite construction techniques. 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 driving factor is the single most important factor was driving the use of offsite construction techniques. Both consultants and contractors responded that duration compression is the most important benefit of offsite construction.

Consultants and Contractors Perceptions

According to the reported perceptions 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) labor congestion in site, 6) increase in labor productivity,7) increase in safety in construction site, 8) increase in design efficiency, 9) increase in management efficiency and 10) overall savings in cost. Further, the reported challenges are transportation feasibility and limited options for design. The Linear relationship between consultants and contractors perceptions is 90.9%. The spearman's ranking correlation was 0.999475.

Comparison of Contractor Categories as per PEC

The comparison of contractor categories are shown in Table 3.The spearman's correlation factor is 0.6843 for contractor's categories which shows 68.43% similarity of ranking between these categories. As different kind of works for each category have different offsite practices along with variation in planning strategies, design tools, options and software, the categories of contractor shows difference of ranking in project planning, complicated software for design, limited options for design as barriers for offsite construction.

Comparison of Consultants Construction Sectors

The sector wise comparison of consultants are shown in Table 4. The spearman's correlation factor is 0.982766, which suggests 98.27% similarity of ranking between consultant sectors. Consultant sectors show different ranking in decrease of labors and increase in jobsite management efficiency in offsite construction.

Comparison of Contractors Construction Sectors

The sector wise comparison of contractors are shown in Table 5. The spearman's correlation factor is 0.947896, suggesting 94.78% similarity of ranking between contractor sectors. Major difference of ranking is due to constraints in project planning, changes in onsite work and software for design. As contractors are much aware about changes in design, if proper planning be done, fewer changes will be required in onsite work.

Sector Wise Relationship of Consultants and Contractors

. Residential sector shows 20.9% linear relationship 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 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. . There is no relationship whatsoever between consultants and contractors sector wise about offsite construction techniques

CASE STUDY

A construction project is undertaken for case study to compare cost and duration of project through offsite and onsite traditional construction approach. A project is 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 kilometers (51 sq mi). Multan division lies between north scope 29′-22′ and 30′-45 and east longitude 71′-4′ and 72′-4'55. The city is placed on the banks of the Chenab River in the geographic focus of the nation. Multan characteristics a bone-dry atmosphere with exceptionally hot summers and mild winters. The city witnesses probably the most compelling climate in the nation. The most noteworthy recorded temperature is give or take 54 °c (129 °f), and the least recorded temperature is pretty nearly −1 °c (30 °f). The normal precipitation is around 186 millimeters (7.3 in). Dust storms are a typical in city.

The project consists of 4 floor frame structure building with minimum compressive strength of concrete of 3000 psi and in slabs, beams, columns and footing of 3750 psi. The steel yield strength of 60000 psi. The cement used in project is Portland cement. The water cement ratio of 0.4. The initial setting time of cement was 45 minutes. The hanger bars of #4 @ 12" C/C and the reinforcement in slabs and footings are of #4 bar @ 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 are 3/4", 1.5", 1.5" and 1".

The cost estimation of project is done through 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, in offsite construction only beams and slabs were taken in account. By doing cost comparison between traditional onsite construction and offsite construction of a construction project. The cost estimates tell that offsite construction cost is 10.9% less than onsite traditional construction.

The schedule comparison of project is done through traditional onsite approach and offsite construction approach. By doing comparison we got traditional onsite construction and offsite (Taking Precast Slab and Beams only) construction approaches duration.

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) X 100
= 10%

Therefore we came to know that a project done by offsite construction takes 10% less time to accomplish than traditional onsite construction

CONCLUSION

Offsite construction techniques are used worldwide but only precast and prefabricated products are used in Pakistan. According to perceptions of consultants and contractors offsite construction has many benefits as well as challenges. 1) Decrease in project duration, 2) need for skilled workers, 3) reduction in onsite congestion, 4) negative impact of other operations, 5) labor congestion on site, 6) increase in labor productivity, 7) increase in safety in construction site, 8) increase in design efficiency, 9) increase in management efficiency and 10) overall savings in cost are possible benefits of offsite construction. But there are challenges which hamper these advantages, such as transportation feasibility and limited options for design are challenges in offsite construction. It is clear from findings that environmental impact will be less in offsite construction as compared to onsite construction

Findings indicate PEC categories of contractors have different perceptions about offsite construction. There are also different perceptions of consultants and contractors in residential, commercial, infrastructure and industrial sectors about offsite construction.

RECOMMENDATIONS

Offsite construction has many benefits as well as challenges. These techniques are used to an extent of only 11 – 20% in Pakistan. Different countries in world have done marvelous work from offsite construction. That's why it is recommended to use offsite construction in Pakistan to gain its benefits and also to take some steps to overcome its challenges from research and development.

Table 1. Seven point Likert scale

1	Strongly disagree	5	Slightly agree
2	Moderately disagree	6	Moderately agree
3	Slightly disagree	7	Strongly agree
4	Neither agree nor disagree		

Table 2. Contractor categories in Pakistan

CA	No limit of construction cost	C3	Construction cost limit up to 400 million PKR
CB	Construction cost limit up to 3000 million PKR	C4	Construction cost limit up to 150 million PKR
C1	Construction cost limit up to 1800 million PKR	C5	Construction cost limit up to 50 million PKR
C2	Construction cost limit up to 800 million PKR	C6	Construction cost limit up to 20 million PKR

Table 3. Contractor categories in Pakistan

Hypothesis statement of Questions	CA	CB	C1	C2	C3	C4	C5	C6
Limit changes in onsite work	×	✓	✓	✓	✓	✓	✓	✓
Reduces project duration	✓	✓	✓	✓	✓	✓	✓	✓
Reduces need of skilled labors	✓	✓	✓	✓	✓	✓	✓	✓
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	✓	✓	✓	✓	✓	✓	✓	✓
Offsite construction techniques increase project design efficiency	✓	✓	✓	✓	✓	✓	✓	✓
Cost of design increases	✓	✓	✓	✓	✓	✓	✓	×
Software's for designing offsite methods limit their uses	×	✓	✓	✓	✓	✓	×	×
Increases jobsite management efficiency	✓	✓	✓	✓	✓	✓	✓	✓
Decreases labor congestion	✓	✓	✓	✓	✓	✓	✓	✓
Cost savings increases	×	✓	✓	✓	×	×	×	✓
Labor savings increases	✓	✓	✓	✓	✓	✓	✓	✓
Planning is barrier for offsite methods	✓	×	×	×	×	✓	×	×

Table 4. Sector wise comparison of consultants

Hypothesis statement of Questions	Residential	Commercial	Industrial	Infrastructure
Limit changes in onsite work	✓	✓	✓	✓
Reduces project duration	✓	✓	✓	✓
Reduces need of skilled labors	✓	×	×	×
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	✓	×	✓	✓
Offsite construction techniques increase project design efficiency	✓	✓	✓	✓
Cost of design increases	✓	×	✓	✓
Software's for designing offsite methods limit their uses	×	×	✓	✓
Increases jobsite management efficiency	✓	×	✓	×
Decreases labor congestion	✓	✓	✓	✓
Cost savings increases	×	✓	✓	✓
Labor savings increases	✓	×	✓	✓
Planning is barrier for offsite methods	✓	✓	✓	×

Table 5. Sector wise comparison of contractors

Hypothesis statement	Residential	Commercial	Industrial	Infrastructure
Limit changes in onsite work	✓	✓	✓	✓
Reduces project duration	✓	✓	✓	✓
Reduces need of skilled labors	✓	✓	✓	✓
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	✓	✓	✓	✓
Offsite construction techniques increase project design efficiency	×	✓	✓	✓
Cost of design increases	×	✓	✓	✓
Software's for designing offsite methods limit their uses	×	✓	✓	×
Increases jobsite management efficiency	✓	✓	×	✓
Decreases labor congestion	✓	✓	✓	✓
Cost savings increases	✓	✓	✓	✓
Labor savings increases	✓	✓	✓	✓
Planning is barrier for offsite methods	✓	×	×	×

REFERENCES

[1] Hsieh, T. Y. (1997). The economic implications of subcontracting practice on building prefabrication. *Automation in construction*, *6*(3), 163-174.

[2] Barlow, J. (1999). From craft production to mass customization. *Housing Studies*, 14(1), 23–42.

[3] Lu, N., & 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*, 4(3), 177-188

[4] Gotthelf, H., Ozbek, M. E., & Guggemos, A. (2013). Potential Efficiency Gains from Early Involvement of Steel Fabricators and Erectors: Lessons Learned from the NREL Research Support Facility Project. *International Journal of Construction Education and Research*, *9*(2), 147-160.

[5] Azhar, S., Lukkad, M. Y., & Ahmad, I. (2013). An Investigation of Critical Factors and Constraints for Selecting Modular Construction over Conventional Stick-Built Technique. *International Journal of Construction Education and Research*, 9(3), 203-225.

[6] Construction Industry Institute. (2002). Develop a decision support tool for prefabrication, preassembly, modularization, and off-site fabrication. (CII Publication No. RR171-12). The University of Texas at Austin, Austin.

[7] Gann, D. M. (1996). Construction as a manufacturing process? Similarities and differences between industrialized housing and car production in Japan.*Construction Management & Economics*, *14*(5), 437-450.

[8] Hyari, K., El-Mashaleh, M., & Kandil, A. (2010). Optimal assignment of multiskilled labor in building construction projects. *International Journal of Construction Education and Research*, *6*(1), 70-80.

[9] Tam, C. M., Tam, V. W., Chan, J. K., & Ng, W. C. (2005). Use of prefabrication to minimize construction waste-a case study approach. *International Journal of Construction Management*, *5*(1), 91-101.

[10] Blismas, N., Pasquire, C., & Gibb, A. (2006). Benefit evaluation for off-site production in construction. *Construction Management and Economics*, *24*(2), 121-130.

[11] Construction Industry Institute. (1998). Multiskilling labor strategies in construction: Implementing mutltiskilling in the construction industry (CII Publication No. RR137-13). The University of Texas at Austin, Austin.

[12] Edge, M., et al. (2002). Overcoming Client and Market Resistance to Prefabrication and Standardization in Housing. UK Department of trade and industry: *UK Engineering & Physical Research Council*.

[13] Gibb, A. G. (1999). *Off-site fabrication: prefabrication, pre-assembly and modularisation*. John Wiley & Sons.

[14] Gibb, A., & Isack, F. (2003). Re-engineering through pre-assembly: client expectations and drivers. *Building Research & Information*, *31*(2), 146-160.

[15] Memarian, B., & Mitropoulos, P. (2014). Production System Design for Speed and Reliability: A Case Study in Concrete Construction. *International Journal of Construction Education and Research*, (ahead-of-print), 1-20.

[16] O'Connor, J. T., Tucker, R. T., Eickmann, J. A., & Fagerlund, W. R. (2000). *Prefabrication and*

preassembly trends and effects on the construction workforce. Center for Construction Industry Studies.

[17] Kumar, R. (2005). Research methodology (2nd ed.). *Thousand Oaks*, CA: Sage Publications Ltd.

[18] Liska, R. W., & Piper, C. A. (1999). *Attracting and maintaining a skilled construction workforce*. Research Report 135-11). Clemson, SC: Construction Industry Institute.

[19] Farnsworth, C. B., Beveridge, S., Miller, K. R., & Christofferson, J. P. (2014). Application, Advantages, and Methods Associated with Using BIM in Commercial Construction. *International Journal of Construction Education and Research*, (ahead-of-print), 1-19.

[20] Li, Z., Shen, G. Q., & Xue, X. (2014). Critical review of the research on the management of prefabricated construction. *Habitat International*, *43*, 240-249.

[21] Pan, W., Gibb, A. G., & Dainty, A. R. (2008). Leading UK housebuilders' utilization of offsite construction methods. *Building Research & Information*, *36*(1), 56-67.

[22] Pan, W., & Sidwell, R. (2011). Demystifying the cost barriers to offsite construction in the UK. *Construction Management and Economics*, *29*(11), 1081-1099.

[23] Tatum, C. B., Vanegas, J. A., & Williams, J. M. (1986). *Constructability improvement using prefabrication, preassembly* (No. 297). And modularization, Technical Report.

[24] Piroozfar, P., Altan, H., & Popovic-Larsen, O. (2012). Design for sustainability: A comparative study of a customized modern method of construction versus conventional methods of construction. *Architectural Engineering and Design Management*, *8*(1), 55-75.

[25] Kotrlik, J. W. K. J. W., & Higgins, C. C. H. C. C. (2001). Organizational research: Determining appropriate sample size in survey research appropriate sample size in survey research. *Information technology, learning, and performance journal*, *19*(1), 43

[26] CMAA. (2006). FMI=CMAA Sixth annual survey of owner [WWW document]. URL http://cmaanet.org/foundation_research.php