



Adoption of Prefabrication in Small Scale Construction Projects

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Received 07 September 2018; Accepted 03 April 2019

Abstract

The construction industry is facing numerous difficulties in managing construction waste, quality, environment, permanence, safety, and greater construction cost. Dynamic change is needed today to overcome new challenges in the construction industry. Adoption of prefabrication is one of the possible solutions to such problems. This paper explores the advantages in prefabrication adoption with its possible disadvantages (barriers) through the qualitative study. This paper is an addition to the existing literature of prefabrication specially for developing countries where the acceptance rate of new approaches is difficult. It covers private residential project and a public housing project. This study also aims to evaluate the current status of prefabrication adoption in small-scale construction projects. A set of the questionnaire is used to collect the data and Average Index (AI) method using SPSS has been used to analyze the results. Shorter construction time, Low site waste and better supervision are the main advantages. Higher initial construction cost and Strict & difficult design changes are the key disadvantages. It is analyzed that the conventional construction method is more frequently used when compared with prefabrication concept.

Keywords: Prefabrication; Waste Management; Small Scale Projects.

1. Introduction

Increasing awareness of environmental, social and economic issues in today's building methods has allowed practitioners around the world to adopt practices that are considered more sustainable in the long term. In the construction industry, conventional on-site construction methods have long been criticized for their durability, low productivity, low level of safety and a large amount of waste [1, 2]. As an alternative to these problems, prefabrication can provide significant benefits, such as reduced time, low waste, improved quality, reduced environmental emissions, improved work environment, and reduced energy and water consumption [3, 4]. One of the main reasons for the discouragement of decision-makers to adopt prefabrication is that they have difficulty in finding the benefits that such an approach would add to a project [5]. In fact, prefabrication is not always the only solution available, and it is not always better than the on-site construction method because of the different characteristics of the project and the resources available. If not used properly, orders lag significantly behind the production, cost overruns and structural problems in the use of prefabrication. Deciding to use prefabrication based on confidentiality and personal preferences is not uncommon [6]. Pasquire and Connolly (2002) has shown that the decision to include prefabrication still relies heavily on subjective evidence, rather than hard data, as there are no formal measurement strategies [5].

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 <http://dx.doi.org/10.28991/cej-2019-03091314>



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Prefabrication is widely regarded as a sustainable construction method with regard to its impact on the protection of the environment. An important aspect of this perspective is the influence of prefabrication on the reduction of construction waste and subsequent waste management activities, including waste categorization, recycling and disposal [7]. Recent studies reported that in order to cope up with the challenges in speed and quality in the construction industry to offset the shortage of houses for growing population in any country, the need of the day is prefabrication [8]. The use of prefabrication technology can contribute to waste reduction significantly. On condition that more detailed designs, waste reduction during construction could be achieved by avoiding unsuccessful works and unnecessary repetition of works [9]. Compared with the traditional cast-in-place method, it has been unable to meet the requirements of the construction industry and the development of the times. Because the prefabricated building has the advantages of fast speed, water saving, land saving, noise reduction, material saving and energy saving in installation [10]. Zhai (2017) explored the effect of operative hedging and develops the coordination mechanism towards a definite hedging problem in the prefabricated construction supply chain management [11]. Bon-Gang et al. (2018) reported that prefabrication can improve the workflow continuity, increase the efficiencies in the use of resources, minimize construction wastes, and reduce the number of on-site contractors as well as construction durations [12]. Many studies have focused on the technologies and reasoning behind off-site construction [13]. Prefabricated construction has attracted worldwide concern because of its significant role in the creation of sustainable urbanization [14]. Prefabrication is an innovative and cleaner approach that has restructured the production of the construction industry [12]. Fard et al. (2015) highlighted that prefabrication is also prone to occupational accidents so it is also important to evaluate it [15].

Prefabricated construction is becoming more common, improved in quality and has become available in a variety of costs. Many benefits are reported for this approach, including green approaches, financial savings, and flexibility in design, consistent quality, reduced site disruption, reduced construction time, and improved productivity. The results of Jaillon and Poon (2008) showed that the environmental, economic and social benefits of prefabrication were significant compared to conventional construction methods [9]. This implies that wider use of prefabrication techniques can contribute to sustainable construction in a close urban environment. In order to improve the overall quality and efficiency, it is necessary to increase the way the construction is carried out and revised. The key lies in innovation and blocking the many barriers that limit the sector's enormous potential to create a sustainable built environment. Hence, it is essential to evaluate this panorama that would encourage the suitable discussion of the appropriateness of prefabrication and other construction methods. Thus, this paper is an initial step toward this serious problem. The study aims to identify advantages of prefabrication and barriers in the adoption of it. It also aims to investigate the current status of prefabrication adoption in the construction industry of Pakistan. This paper will provide a pre-requisite knowledge and scenario of prefabrication adoption in making small-scale building projects. The results of this study may lead to a broader research for prefabrication adoption in big and complex construction projects.

2. Sustainability Aspects of Prefabrication

Sustainability enables a holistic response to environmental, social crises and creates the necessary links between nature, culture, economy, politics and technology. Prefabricated elements provide environment-friendly, energy and cost-efficient solutions for the building [16]. Prefabricated modular structures are increasingly becoming popular [17, 18]. This is starting to lead customers to consider the effects of the sustainability of the construction, operation and maintenance of projects. Today's World is striving to cope up with upcoming challenges including saving natural resources, enhanced use of recycled items, environmental degradation, the overall cost of construction item and so on. All of this can be achieved by enforcing existing sustainability theories and modifying the sustainability aspects. The result of this struggle, which is evident in the highly developed and still developing countries, is closely linked to the pressures of economic progress. The framework for sustainable infrastructure design should review the economic impact of new prefabricated and construction technologies.

3. Research Methodology

An extensive literature review has been made to explore the gape in the existing body of knowledge for prefabrication and its acceptance level in different countries followed by Pakistan. After identify a gape, a research method was designed to carry out this research work. In the later stage, pilot studies were conducted to seek stakeholder's opinion for the prefabrication and its factors and finally a set of questionnaire was designed to collect data from the construction industry. It is observed that Average Index has been successfully used as a decision-making approach for such data set so the same approach is adopted for this study. The final ranks are based of this approach. The complete research methodology is shown in Figure 1.

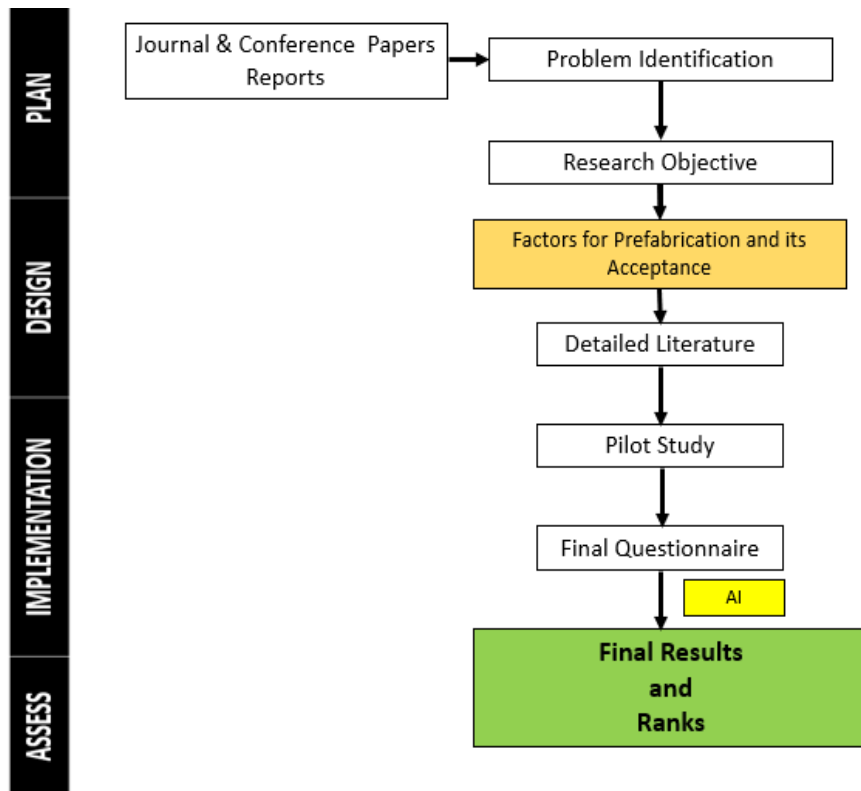


Figure 1. Research Method

4. Data Collection and Analysis

A detailed literature review has been made for factor identifications in this research. The identified factors were processed through a short pilot study. Expert’s opinion during pilot study is amended in final set of questionnaire which was send to numerous practitioners working in construction industry via hard mail and emails. The respondents were requested to share their experience in assess the adoption level of prefabrication, advantages and disadvantages of prefabrication in general and with specific reference to small scale residential projects at private side and government side. Finally, 159 questionnaires were considered for this research which was received during data collection period.

Average Index (AI) method has been successfully used for data analysis of such decision-making problems. Therefore, same is used for data analysis of this paper. Average Index is indexed as shown in Eq: 1

$$\text{Average Index} = \left[\frac{\sum_{i=1}^5 a_i X_i}{5 \sum_{i=1}^5 X_i} \right] \tag{1}$$

Where, a_i = Constant expressing the weight given to i , X_i = variable expressing the frequency of the response for:

5. Results and Discussion

As discussed earlier, the respondents were requested to share their opinion based on their work experience in construction industry. The respondents were provided with a 4-point likert scale and requested to weight the factors which are advantageous for prefabrication in construction industry of small-scale residential building projects. Table 1 shows the rank of factors which are advantageous for prefabrication based on AI score.

Table 1. Ranking of Prefabrication Advantages

Sr. No.	Advantages of Prefabrication	AI Score	Rank
1	Shorten construction time	3.57	1
2	Low site waste	3.48	2
3	Better supervision	3.46	3

4	Sustainable product (reusable, reinstalled)	3.46	3
5	Environmentally friendly	3.23	4
6	Reduce overall construction cost	3.12	5
7	Better quality	3.12	6
8	Improved aesthetic	3.05	7
9	Low design problems	3.03	8
10	Work is not affected by weather delays (related to excessive cold, heat, rain, snow, etc.)	3.03	8
11	Less theft of material/equipment (and less property damage due to vandalism)	3.00	9
12	Reduction of energy and water consumption	3.00	9
13	Enriched durability	2.92	10
14	Precise conformity to building code standards	2.91	11
15	Better occupational health and safety	2.91	11
16	Worker comfort level is higher than in site-built construction	2.87	12
17	Computerization of the production process permits a high degree of customization	2.70	13
18	Allows for year-round construction during any climate	2.70	13

It is observed that shorten construction time and less construction site waste are ranked as first and second with an average mean value of 3.57 and 3.48 respectively. It indicates that while adopting prefabrication in construction, will cause the overall shorten project duration and due to the manufacturing of components at particular site or in factory it will result less construction site waste. Also, the better supervision, sustainable product and environmentally friendly are ranked as third and fourth and followed by others as shown.

Other than the advantages in adopting prefabrication, the disadvantages on the applications of prefabrication are also investigated in this research. Similar analysis has been made for this phase of the research. Table 2 shows the responses on the disadvantage (hindrances) in applying prefabrication in building construction projects.

Table 2. Ranking of Prefabrication Disadvantages

Sr. No	Disadvantages of Prefabrication	AII Score	Rank
1	Higher initial construction cost	3.25	1
2	Strict & difficult design changes	3.12	2
3	Time consuming in initial design	2.91	3
4	Leakage problem while joining prefabricated components	2.87	4
5	Lack of availability of prefabricated industries	2.85	5
6	Lack of skilled labour	2.85	5
7	Lack & expensive equipment	2.83	6
8	Limited site space	2.78	7
9	Lack of materials used in prefabrication	2.75	8
10	Fewer demand by clients	2.67	9
11	Government legislations and Guidelines	2.66	10
12	Transport requirements and may limit its scope	2.62	11
13	Limited trained labour	2.62	11
14	Lack of experiences	2.55	12
15	Increased production volume is required to ensure affordability through prefabrication	2.45	13
16	New process and unfamiliarity of process	2.45	13

It is observed that higher initial cost and Strict & difficult design changes are ranked as first and second with an average mean value of 3.25 and 3.12 respectively. Since the prefabricated components are manufactured early at the stage and if in future it is required to change the design of the project then it will be inflexible and prove to be costly. In

addition to it, time consuming in initial design and leakage problems while joining prefabricated components stands at third and fourth factor followed by others as shown.

Finally, current status of the adoption of prefabrication has been assessed in this research. Comprehensive prefabrication method for different elements of projects is shown in Table 3.

Table 3. Adoption Level of Prefabrication in Small Scale Projects

NO.	Building Element	Sub Elements	Private Residential Projects	Public Housing Projects
1	Substructure	Foundation	0%	0%
		Basement	0%	0%
2	Drainage and underground work	Drainage	70%	80%
		Piling	0%	0%
3	Structural frame works	Column	0%	0%
		Beam	15%	5%
		Stairs	0%	0%
		Slab	5%	0%
4	External works	Boundary Wall	30%	60%
		Partition Wall	15%	5%
		Fall Ceiling	100%	100%
5	Internal works	Tiling	75%	80%
		Washroom	15%	10%
		Kitchen	25%	10%

It is observed that private and public sector is widely using prefabrication for fall ceiling. They also use prefabrication significantly for drainage and tiling works. Both sectors use prefabrication for kitchen items, washroom fixtures, boundary walls and partition walls to some stage means they are adopting it for such items for building works. It is observed that both sectors started adopting this concept to some extent for elements like beams, columns and slabs. Whereas, it is also observed that still both sectors lack to use prefabrication concept for foundation, basement, piling and stairs, they are not accepting this idea as a better replacement for cast-in situ elements as mentioned.

6. Conclusion

Prefabrication method for the construction industry provides a much more efficient atmosphere for productivity, eliminating the unnecessary distractions and interference typically encountered in conventional construction sites. It should be noted that prefabrication in most cases takes less than half the time compared to traditional construction. This is due to better planning, design, elimination of on-site problems and meteorological factors, subcontractor scheduling delays and faster manufacturing, as multiple parts can be built simultaneously. Prefabrication is a possible solution to the main causes of waste that arise in design and construction. Prefabrication also contributes to other benefits at the site, such as shorter construction time, better monitoring can be achieved with respect to the environment, improving quality and sustainability. Reducing total construction costs and better aesthetic prospects are also important advantages of prefabrication. Considering the results, it can be concluded that adoption of prefabrication is becoming a norm in building construction, though conventional method is still used in majority of construction industry but looking at scenario of construction in developed countries it seems that the use of prefabrication should likely to increase. With the continued popularity of prefabricated construction, it is likely to continue to grow in popularity. Customers who choose this option can benefit from a high-quality, faster, cost-effective and environmentally friendly construction method.

7. Acknowledgement

The authors are thankful to Mehran University of Engineering & Technology, Jamshoro, Pakistan for providing platform to conduct this research at master's level. The authors also extend their gratitude to Prince Sultan University, Riyadh, Saudi Arabia for expertise role throughout this research study.

8. Conflicts of Interest

The authors declare no conflict of interest.

9. References

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