Prefabrication As A Solution To Improve Productivity Of Construction Industry, Tamilnadu, India

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Abstract- Prefabricated construction system has been proven effective, sustainable, and labor-friendly to the construction industry. . India is still in the initial process of adopting prefabricated construction practices and has conducted a few studies to date on the constraints of prefabricated construction up to the operation stage. This paper focuses on benefits, difficulties and measures in adoption of prefabrication in Tamil Nadu, India and offers some recommendations on extent usage of prefabrication. Twenty-four criteria, ten criteria for benefits in adopting prefabrication and seven criteria for difficulties in prefabrication and seven criteria for measures in adopting prefabrication are summarized as per the results of a literature review. A questionnaire was delivered to builders / constructors, architects, engineers, and client/ developers. A total of 65 valid respondents were collected. Based on severity index all the parameters were ranked accordingly. The findings presented in this paper may assist different stakeholders in better understanding issues with prefabricated construction practices in Tamil Nadu, India at present and, therefore, find workable solutions.

Index Terms- Prefabrication, Sustainable, Severity Index, Quality, Cost, Time

I. Introduction

Indian Infrastructure and Construction sector has grown exponentially in the last few decades and the Government of India (GOI) have identified the sector as a major driving factor for the economic development of the country. India's infrastructure market is the third-largest in Asia and it includes power, bridges, dams, roads and urban infrastructure development [1]. According to Indian Construction Market – Growth, Trend and Forecast (2020-2025) report, the Indian construction market is expected to register a Compound Annual Growth Rate (CAGR) of 6% over the forecast period, 2019 – 2024. Infrastructure sector plays and vital role in the growth and development of the Indian economy. Nearly, 9% of India's GDP is spent on Infrastructure services. The construction industry plays a vital role in the development of the Indian economy by introduction of new system and technologies of construction. Prefabrication construction system is being used widely by many countries around the world for its potential to increase productivity and efficiency while not sacrificing quality. In India the uptake of prefabrication technologies continues to remain slow and prefabricated buildings comprise only 1 per cent of India's $100 Billion Real Estate Market. The main reason for this being that Prefabrication as a technology is still battling a mindset blockade in India, with most developers averse to investing in modular methods of construction and hesitant to incorporate prefabrication in their new and ongoing projects [2]. The adoption of prefabrication will save construction time, reduce construction cost, lightweight and durable and sustainable in all aspects. Prefabrication has the capacity to offer alternative choice of solutions to the conventional construction methods adopted in India. This paper provides an overview of benefits, difficulties and measures in adoption of prefabrication in Tamil Nadu, India and offers some recommendations on extent usage of prefabrication.

II. Research Methodology

Methodology selected for this research comprised of a questionnaire design, a questionnaire survey and interviews of the stakeholders of construction industry and a statistical analysis of the survey data.

A.Questionnaire Survey

From extensive review of literature it was observed that there was no comprehensive list of performance criteria to identify the benefits, difficulties and measures in adopting prefabrication construction system. To compile a meaningful list of criteria, a critical review was conducted in related areas. Based on the derived criteria, an industry questionnaire survey was designed. The survey, which consisted of three main parts, aims at investigation the perspective of the construction industry on the benefits, difficulties and measures in adopting prefabrication construction system in the study area. The respondents were asked to rate the level of importance of the derived criteria based on a scale of 1–5, where 1 is 'Strongly Disagree', 2 'Disagree', 3 'Acceptable', 4 'Agree', and 5 'Strongly Agree'. To ensure a better understanding of the criteria, definition of each criterion was clarified and guidance on completion was given in the questionnaire. Survey questionnaires were emailed to 180 stakeholders comprising of builders / constructors, architects, engineering consultants and client/developers within Tamil Nadu, India.

B.Data Analysis

To ensure that the rating scale (1–5) for measuring the criteria yields the same result over time, a reliability analysis using the internal consistency method was first examined. In order to identify the relative importance of adoption of prefabrication construction system based on the survey data, ranking analysis was performed. It was observed that the ratings in the scale indicate only a rank order of importance of the criteria, rather than how much more important each rating is than the other. Using parametric statistics (means, standard deviations, etc.) to rank such data would not produce meaningful results, and therefore non-parametric procedures must be adopted [3]. Severity index (SI) analysis was selected in this study to rank the criteria according to their relative importance. Five important levels are transformed from SI values: High (H) (0.8≤SI≤1), High–Medium (H–M) (0.6≤SIb0.8), Medium (M) (0.4≤SIb0.6), Medium–Low (M–L) (0.2≤SIb0.4), and Low (L) (0≤SIb0.2).

III. RESULTS AND DISCUSSIONS

After the questionnaire was delivered and a follow-up reminder letter was sent to the respondents who had not returned the survey, a total of 65 responses were received. Among those 65 responses, 21 completed responses were from builders / constructors, 28 from engineers, 4 from architects, and 12 from clients / developers with an overall response rate of 36.11%. All of the survey participants were experienced construction experts. About 10% of them had more than 20 years of experience in the construction industry, 35% had experience between 16 and 20 years, 45% between 10 and 15 years and 10% less than 10 years. The severity index values were calculated and based on the magnitude of the severity indices, the ranking results for each category for all criteria are presented in descending order as shown in Table 1.

Table 1 Rank of performance criteria for adoption of prefabrication construction method.

Performance Criteria	Severity Index	Ranking by category	Importance Level
Benefits in adopting Prefabrication			
B1: Shorten construction time	0.951	1	H
B2: Reduce construction cost	0.908	2	H
B3 : Better Quality	0.907	3	H
B4 : Achieving Green Goals	0.855	4	H
B5 : Improve environmental performance / sustainability	0.840	5	H
B6 : Better Supervision	0.825	6	H
B7 : More adaptable to climatic conditions	0.818	7	H
B8 : Reduce construction waste	0.815	8	H
B9 : Integrity of the building	0.803	9	H
B10 : Fewer onsite resources	0.597	10	M
Difficulties of Prefabrication			
D1 : Inadequate suppliers of prefabrication	0.892	1	H
D2 : Inflexible for design changes	0.874	2	H
D3 : Lack of technical training	0.862	3	H
D4 : Lack of adequate transport and logistics	0.837	4	H
D5 : Proprietor do not want prefabrication	0.828	5	H
D6 : Not included in the design	0.818	6	H
D7 : Development type is not appropriate	0.809	7	H
Measures in adopting Prefabrication			
M1 : Inclusion of technical training	0.942	1	H
M2 : Advancement in prefab skills in workers	0.908	2	H
M3 : Environment / sustainability as the first priority	0.862	3	H
M4 : Government/stakeholder to invest in prefab development	0.822	4	H
M5 : Regulated Policy / Codal Provisions	0.812	5	H
M6 : Incentive scheme to inspire private sector	0.809	6	H
M7 : Adopting prefabrication to the future projects	0.800	7	H

A. Benefits in adopting Prefabrication

Based on these ranking results, nine criteria were highlighted to have high importance level in evaluating benefits in adopting prefabrication with a severity index value between 0.951 to 0.803. These nine criteria are shorten construction time (B1), reduced construction cost (B2), better quality (B3), achieving green goals (B4), improve environmental performance / sustainability (B5), better supervision (B6), more adaptable to climatic condition (B7), reduce construction waste (B8) and integrity of the building (B9). From the analysis it was observed that shorten construction time (B1) ranked 1 with a severity index 0.951. The prefabrication construction system provides a significant reduction in time [5]. Construction time for prefabrication is less than half of on-site construction [6]. Up to 70% time saving can be achieved when compared in-situ construction and average reduction in construction time can achieve 20% when compared with onsite construction [4].

The prefabrication design has different complexities and pre-project planning is quite important for prefabrication construction system. Prefabrication require more engineers, quality controllers and skilled labourers, these requirements will increase the cost of the design phase [5]. The higher initial and transportation costs are the main economic hurdles of prefabricated versus conventional construction methods. From a multiple case studies carried out by many researchers the total cost of prefabricated construction is significantly higher than that of conventional construction methods [7]. Further, from various research papers it was observed that cost of pre-cast may vary with the type and the size of construction. For a small project the cost of pre-cast increases due to no production of elements in bulk. However, for bigger projects the cost may decrease significantly [8]. From the literature and questionnaire analysis it was found that reduce construction cost (B2) play a vital role in prefabrication construction system and ranked two in our study with a severity index 0.908. Better quality (B3) of the end product was ranked third by the respondents, since prefabrication is done under factory control environment. The quality of construction has the potential to reduce the cost as well as the time of any project.

Achieving green goals (B4) and Improve environmental performance / sustainability (B5) ranked fourth and fifth rank respectively with a severity index of 8.55 and 8.40 respectively. In the era of marching towards sustainability, the prefabrication construction system is a key tool to achieve green / sustainable goals. Prefabrication can be attained through better supervision since prefabrication usually has a greater potential for automation (e.g., digital fabrication) and intelligent management systems as well as workers in a prefabrication plant are able to be more proficiently experienced at specific tasks [4]. It was observed from our analysis better supervision (B6) ranked sixth with a severity index 8.25. More adaptable to climatic conditions (B7) ranked seventh with a severity index 0.818. Prefabrication is independent of adverse weather which has almost no impact on the schedule of the prefabrication manufacturing since it is done under factory control environment. Reduction in waste (B8) and Integrity of Building (B9) ranked eighth and ninth with a severity index 0.815 & 0.803 respectively. Prefabrication has many environmental benefits over conventional approaches in the construction phase and has greater performances regarding sustainable construction in terms of construction waste [9]. The least ranked parameter was fewer onsite resources (B10) with a mean value of 2.98 and severity index 0.597. The severity index is medium ($0.4 \leq SI < 06$), because Precast beams and slabs eliminate field forming and shoring requirements and less finish works is required to complete at on-site.

B. Difficulties in adopting Prefabrication

Apart from the benefits attributed to the usage of prefabrication, on the other side equal amount of difficulties are identified by many researchers in the adoption of prefabrication. For the purpose of this study seven criteria were accounted as presented in Table 1. Based on these ranking results, seven criteria were highlighted to have high ($0.8 \leq SI < 1$) importance level in evaluating benefits in adopting prefabrication with a severity index value between 0.892 to 0.818. These seven criteria are inadequate suppliers of prefabrication (D1), inflexible for design changes (D2), lack of technical training (D3), lack of adequate transport and logistic (D4), proprietor do not want prefabrication (D5), not included in the design (D6) and development type is not appropriate (D7).

From the analysis it was observed that inadequate suppliers of prefabrication (D1) ranked 1 with a severity index 0.892. With the advantages outstripping the disadvantages, prefab homes can be a successful construction model in developing economies like India. India's growing interest in such construction has led to global makers of prefabrication machinery and parts, entering the country. There is an immediate need for popularisation and extensive use of prefabricated structures to increase the efficiency, quality and speed of construction and creation of more awareness among common people. The prefabrication technique has a clear-cut role to play in the Indian real estate sector to take it to the next level. It is all set to redefine the future of housing sector in India through introducing many suppliers of prefabrication. It was observed that there were few small scale prefabricated suppliers in the study area and this was a factor that could affect the adoption of prefabrication [10].

Inflexible for design change (D2) and lack of technical training (D3) ranked second and third in difficulties in adopting prefabrication with a severity index 0.874 & 0.862 respectively. The most of the respondents selected inflexible for design changes as a main hindrance in prefabrication, due to the standardised nature of prefabrication it is difficult to alter the design in later stage. As most construction work requires modifications to be done on-site, prefabrication limits the option of alterations in the design scope of the building [11]. Lack of technical training was seen as one of the most important issue in the adoption of prefabrication in India, the survey revealed that most of the stakeholders had theoretical knowledge but no practical training in the usage of prefabrication. Skilled labour is required in prefabrication, as precision assembly of the home is necessary, else improper assembly can result in issues such as joint failure and leaks. It can be concluded that the lack of technical training would have a negative impact on the adoption of prefabrication. The lack of skill labour can be addressed through Technical training programmes to equip construction workers with the adequate technical expertise required to carry out prefabrication work.

Lack of adequate transport and logistics (D4) ranked fourth with a severity index 0.837. Because parts and modules for prefabrication tend to be large, some sites with limited access and /or limited on-site space may not be suitable for prefabrication. Prefabrication are also not suited to smaller sized projects because of the expensive transportation of the larger assembled modules to sites [7]. The limited number of manufacturers of prefabrication means that some project sites may be at large distances from the nearest manufacturer. As a result, the large and heavy loads need to be transported long distances, leading to expensive transportation costs [10].

Some of the clients do not want prefabrication method of construction because, they felt that, either the cost would be high or the construction personnel do not have what it takes to execute prefabrication works so many respondents ranked proprietor do not want prefabrication (D5) as fifth with a severity index 0.828. It was observed from analysis, not included in the design (D6) ranked sixth with a severity index 0.818, since prefabrication structures cannot be customized, they have only limited number of designs. The life of buildings is 50-80 years and sometimes even more and the requirement and lifestyle changes a lot over the years. Many time it needs to modify the indoor space and this option is not available with design of prefabrication buildings [10]. Development type not appropriate to use prefabrication was ranked seventh with a severity index 0.809. The respondents discussed that some of the projects they execute were such that, they were not appropriate to use prefabrication because, the projects were complex and not standardized, and in some instances the projects were small and did not require repetition in any form which is the main advantage of prefabrication.

C. Measures in adopting Prefabrication

Adoption of prefabrication is constrained by a lot of challenges at the project level and at the industry level. Considering the challenges faced, there is a need to address these concerns for the adoption of prefabrication technology at the sector level. This study identified some recommendations for the promotion, effective development and adoption of prefabrication in the construction industry in Tamil Nadu and India as a whole. The criteria selected to view the ideas of stakeholders in adoption of prefabrication were presented in Table 1. Based on ranking results, seven criteria were highlighted to have high ($0.8 \leq SI < 1$) importance level in evaluating benefits in adopting prefabrication with a severity index value between 0.892 to 0.818. These seven criteria are inclusion of technical training (M1), advancement in prefab skills in workers (M2), environment / sustainability as the first priority (M3), government / stakeholder to invest in prefab development (M4), regulated policy / codal provisions (M5), incentive scheme to inspire private sectors (M6) and adopting prefabrication to the future project (M7).

The respondents rated inclusion of technical training (M1) and advancement in prefab skills in workers (M2) ranked first and second with a severity index 0.942 & 0.908 respectively. This survey revealed that, there is lack of practical knowledge on prefabrication skills among workers in the construction industry in the study area. Prefabrication method of construction require special skills in their execution and lack of it will adversely affect its adoption, the education sector must ensure that, practical training are incorporated in the curriculum and Technical training institutions to ensure practical training in the execution of prefabrication works to be taught during training. On the contrary the usage of prefabrication can also be adopted as a substitute for shortage of skill labour because large components are manufactured in the factory and assembled on site with few workers within a shorter time without compromising on quality.

The privileges of a prefabrication system significantly reduces the time of construction and is sustainable in nature. Since the components are manufactured in controlled environment, it provides environmental benefits like site safety, waste reduction, improved air quality and quality management. From the analysis it is clear that environment / sustainability as the first priority (M3) was ranked third by the respondents with a severity index 0.862. Government/stakeholder to invest in prefab development (M4) and regulated policy / codal provisions (M5) ranked fourth and fifth with a severity index 0.822 & 0.812 respectively. There is an immediate need for popularization and extensive use of prefabricated structures to increase the efficiency, quality and speed of construction by implementing government / stakeholder to invest in prefab development (M4) and regulated policy / codal provision (M5). Further, by introducing incentive schemes to inspire private sectors (M6) which was ranked sixth by the respondents in measures in adopting prefabrication with a severity index 0.809. The adoption of prefabrication for future project as a means to facilitate sustainability in the construction sector was a major item, though least ranked with a severity index 8.00 respectively. However, the severity index falls in the category of High, this shows the respondents are more focused on adopting prefabrication construction system.

The adoption of prefabrication construction system is low, despite their well-documented benefits. In the present study the questionnaire was concluded to examine the importance of respondents' intent to use or recommend prefabrication in future. It was observed from the survey that out of 65 responds 49 said that they would recommend the use or use prefabrication method of construction in future (representing 75.4%) when the need arises, 16 out of 65 respondents reported that they would not recommend or use prefabrication in the future (representing 24.6%).

IV. CONCLUSION

The challenge facing construction practitioners during early project stages is that of selecting an appropriate construction method. The significant benefits of prefabrication construction are commonly cited when justifying the adoption of prefabrication. A prefabrication construction system help reduces cost, environmental friendly, consistent quality and safety. However, there are some barriers in adopting the prefabrication construction system are inflexible for design change, lack of technical training and inadequate suppliers of prefabrication. This research confirms that prefabrication construction system has many sustainable benefits and it was found that majority of stakeholders responded that prefabrication construction system can be adopted in Tamil Nadu, India.

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