CHAPTER 121

Root Cause Analysis in Adaption of Prefabrication Technology in Construction Industry

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ABSTRACT

Prefabrication technologies are increasingly being adopted in the building industry due to their time, cost, and quality benefits. However, there are challenges that hinder their widespread adoption. This study focuses on identifying the root causes (RCA) behind the failure to adopt prefabrication technology. Issues such as enforceability of digital signatures, volatile supply chains, legal exceptions, industry resistance, and incompetent designers are among the problems identified. By combining qualitative and quantitative techniques, the study evaluates the scope of these issues and suggests strategies to address them. The findings show that improving workforce training, legislative support, and supply chain management can significantly enhance the use of prefabrication methods. The research aims to assist in developing frameworks and guidelines to promote the adoption of prefabrication technologies in the construction industry.

Keywords: Prefabrication; Root cause analysis; Workforce training; Average index method.

1.0 Introduction

Prefabricated construction not only promotes better quality control, flexibility, and easier construction, but it also revolutionizes traditional construction site methods—where buildings are often made by hand, without proper planning or foresight. These older methods face challenges like poor weather conditions and other unpredictable factors, which can lead to costly mistakes and inefficiencies.

- *Modular construction:* All building sections of the house are precast and installed on site, suitable for home hotels and student housing.
- *Panelized construction:* Prefabricated wall, floor, and roof panels offer design flexibility.
- *Precast concrete:* Durable concrete elements like walls and beams are cast off-site and transported.
- *Structural steel framing:* Off-site fabricated steel components enable large spans and open spaces.

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- *Prefabricated timber construction:* Sustainable timber elements provide cost-effectiveness and insulation.

1.1 Research objectives

- To identify major barriers to prefabrication technology adoption.
- To analyze the root causes of these challenges using RCA.
- To propose strategic solutions for overcoming these barriers.

2.0 Literature Review

Construction prefabrication is cost-saving, sustainable, and efficient but also presents issues. Beulah (2022) presents serious issues of high cost and change resistance. Palanisamy (2021) focuses on factors and innovation in prefabricated building. Ibrahim *et al.* (2023) employ a Fuzzy-SEM model to present financial, policy, and technological issues to prefabrication. Prefabrication productivity benefits in Tamil Nadu are identified by Murali and K (2020) with flexibility and training concerns. Nor & Azman (2012) contrast traditional and prefabrication practice, with higher use of precast systems. Palcis (n.d.) illustrates the effect of prefabrication on speed, safety, and sustainability. Rocha *et al.* (2022) discuss the effect of prefabrication on environmental and economic sustainability. These studies altogether indicate the potentialities and constraints of prefabrication in various fields and applications.

3.0 Methodology

3.1 Research approach

A mixed-method approach was used, incorporating both qualitative and quantitative data collection methods. Literature reviews and surveys were conducted to gather insights.

3.2 Data collection

- *Primary data:* Surveys and interviews with industry professionals, contractors, and suppliers. The survey focused on identifying the most pressing challenges and possible solutions from industry practitioners.
- *Secondary data:* Review of academic papers, industry reports, and case studies related to prefabrication technology. The secondary data helped in understanding global best practices and comparing prefabrication adoption in different regions.

We have done a survey to identify and rank the factors that are the Root cause in adaption of prefabrication technology in construction industry.

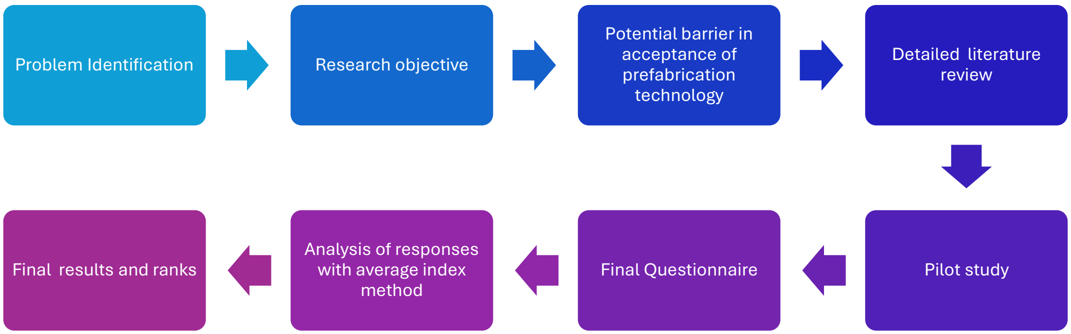
3.3 Research questions and rating scale

Instructions: Please rate the following questions based on their impact on prefabrication adoption.

Scale: (Option for each question)

1. Not Important
2. Slightly Important
3. Moderately Important
4. Important
5. Very Important

Figure 1: Research Methodology.



3.3.1 Transportation and logistics

- Do transportation restrictions (e.g., road width, weight limits) hinder prefabricated component delivery?
- Do high transportation setup costs discourage prefabrication adoption?
- Does the requirement for large-capacity cranes increase logistical challenges?
- Do complex permit requirements for large, prefabricated components delay projects?

3.3.2 Cost & financial constraints

- Does the high initial investment make prefabrication less attractive than conventional methods?
- Do transportation and handling costs of prefabricated components outweigh their benefits?
- Does the lack of government incentives slow prefabrication adoption?

3.3.3 Design & construction challenges

- Does inflexibility in design modifications limit prefabrication adoption?
- Do long lead times for prefabrication components affect project efficiency?
- Does the lack of recognized quality control organizations impact trust in prefabrication?

3.3.4 R&D & innovation

- Does limited investment in research and development hinder prefabrication improvements?
- Does difficulty in integrating prefabrication with traditional methods slow its adoption?

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- Does the lack of advanced digital tools/software create challenges in prefabrication planning and execution?

3.3.5 Regulatory & policy constraints

- Do government policies and regulations fail to support prefabrication adoption?
- Do complex permitting processes for prefabricated components cause project delays and cost overruns?

Figure 2: Pie Chart Showing Roles of the Responders

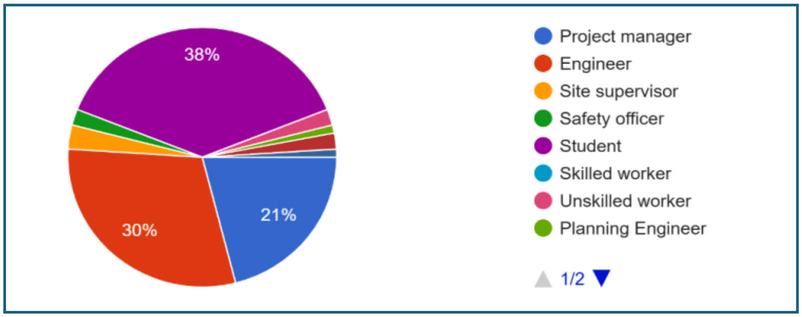
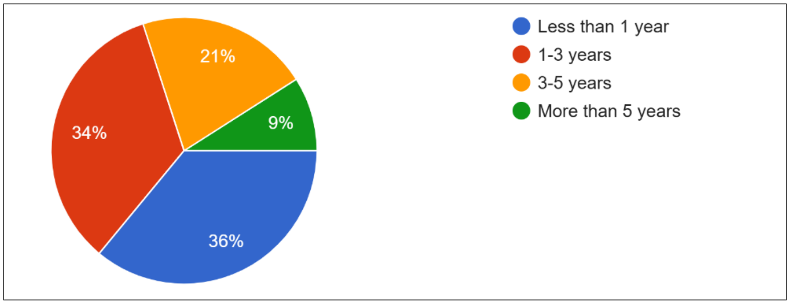


Figure 3: Pie Chart Years of Experience of the Responders



3.4 Data analysis

3.4.1 Average index method

The Average Index Method is a valuable tool in root cause analysis, utilized to identify the key contributing factors of a problem through the analysis of survey or operational data. This method assists in ranking issues based on their significance or frequency.

$$\text{Average Index}=\left[\frac{\sum_{i=1}^{5} a_i x_i}{5\sum_{i=1}^{5} x_i}\right] \qquad \ldots 1$$

Where, ai represents a constant that indicates the weight assigned to i, while Xi denotes a variable that reflects the frequency of the response.

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Table 1: Survey Response Sheet

Survey questions in short	No. of Response as 1	No. of Response as 2	No. of Response as 3	No. of Response as 4	No. of Response as 5
Lack of experienced designers?	5	7	27	40	21
Lack of qualified contractors?	5	8	26	36	25
Shortage of prefabricated component suppliers?	3	9	31	29	28
Investors reluctant to invest?	2	12	23	36	27
Industry resistance to innovation?	3	9	31	35	22
Limited skilled labor for assembly?	3	15	28	33	21
High cost of prefabrication contractors?	2	11	21	41	25
High transportation expenses?	3	7	26	41	23
Lack of government regulations?	3	14	25	38	20
Insufficient training programs?	5	7	29	35	24
Restrictions on transportation?	5	8	26	39	22
High start-up costs for prefabrication?	3	8	24	38	27
Low research & development in prefabrication?	2	9	24	37	28
Complexity in obtaining permits?	2	7	31	32	28
Poor stakeholder collaboration?	3	5	32	34	26

3.4.2 Relative Importance Index (RII)

In the present study, the Relative Importance Index (RII) method was employed to rank the significance of factors influencing the adoption of prefabrication technology within the construction industry. The RII technique is frequently utilized in construction management research to determine the relative weight of responses gathered using a Likert scale. The RII approach is helpful in determining the most important factors affecting decision-making procedures by transforming ordinal data into normalized scale.

$$RII= (5n_5+4n_4+3n_3+2n_2+1n_1)/ 5N \quad ...2$$

where, n_1 = Number of respondents for Not Important

n_2= Number of respondents for Less Important

n_3= Number of respondents for Moderately Important

n_4 = Number of respondents for Important

n_5 = Number of respondents for Very Important

N = Total number of respondents

Using this formula, the RII values of each factor were calculated and the factors ranked in decreasing order according to their relative importance. The greater the value of RII, the more important the factor is in relation to the issue being researched. This analysis offers a structured and metric approach to determining the most important factors, assisting in more informed decision-making and targeting corrective measures.

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Table 2: Data Analysis Sheet

Survey questions in short	Relative importance index score (RII)	Average index method score (AI)	Rank on the basis of RII	Rank on the basis of AI
Lack of experienced designers?	0.73	3.65	11	11
Lack of qualified contractors?	0.736	3.68	9	9
Shortage of prefabricated component suppliers?	0.74	3.7	8	8
Investors reluctant to invest?	0.748	3.74	6	6
Industry resistance to innovation?	0.728	3.64	13	13
Limited skilled labor for assembly?	0.708	3.54	15	15
High cost of prefabrication contractors?	0.752	3.76	4	4
High transportation expenses?	0.748	3.74	6	6
Lack of government regulations?	0.716	3.58	14	14
Insufficient training programs?	0.732	3.66	10	10
Restrictions on transportation?	0.73	3.65	11	11
High start-up costs for prefabrication?	0.756	3.78	2	2
Low research & development in prefabrication?	0.76	3.8	1	1
Complexity in obtaining permits?	0.754	3.77	3	3
Poor stakeholder collaboration?	0.75	3.75	5	5

4.0 Research Findings and Results

4.1 Findings

4.1.1 Key barriers to prefabrication adoption

- The most significant challenge identified is low research & development (R&D) in prefabrication, which ranked highest based on both the Relative Importance Index (RII) = 0.76 and the Average Index Method (AI) = 3.8.
- High start-up costs for prefabrication (RII = 0.756, AI = 3.78) are another major factor preventing the adoption of prefabrication in construction.
- Complexity in obtaining permits (RII = 0.754, AI = 3.77) is a major regulatory barrier affecting the smooth implementation of prefabrication.

4.1.2 Financial and logistical constraints

- High cost of prefabrication contractors (RII = 0.752, AI = 3.76) and high transportation expenses (RII = 0.748, AI = 3.74) are significant cost-related concerns that discourage prefabrication use.
- Investors' reluctance to invest (RII = 0.748, AI = 3.74) indicates financial hesitancy from stakeholders due to uncertainties in return on investment and market viability.

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4.1.3 Skilled labor and industry readiness

- The shortage of prefabricated component suppliers (RII = 0.74, AI = 3.7) and lack of qualified contractors (RII = 0.736, AI = 3.68) highlight a gap in industry expertise.
- The lack of experienced designers (RII = 0.73, AI = 3.65) and insufficient training programs (RII = 0.732, AI = 3.66) indicate the need for better educational frameworks and training initiatives.

4.1.4 Regulatory and structural challenges

- Lack of government regulations (RII = 0.716, AI = 3.58) and industry resistance to innovation (RII = 0.728, AI = 3.64) suggest that policy support and industry mindset shifts are necessary.
- The lowest-ranked factor is limited skilled labor for assembly (RII = 0.708, AI = 3.54), which suggests that while labor shortages exist, they may not be the most critical issue compared to financial and regulatory barriers.

4.2 Results

- The most critical barriers are related to financial feasibility (high start-up costs), lack of R&D, and regulatory complexity.
- The industry is hesitant to invest in prefabrication due to high costs, lack of government incentives, and supply chain constraints.
- Stakeholder collaboration needs improvement, as it ranked among the top challenges (RII = 0.75, AI = 3.75), showing that better coordination among designers, contractors, and suppliers is crucial.
- Addressing skill shortages through training programs and contractor qualification improvements can help mitigate industry readiness challenges.

5.0 Conclusion

The analysis highlights that financial constraints, regulatory hurdles, and insufficient research & development are the most significant barriers to prefabrication technology adoption in the construction industry. Addressing these issues through increased investment in R&D, policy interventions, and improved collaboration between stakeholders can help accelerate the adoption of prefabrication. Additionally, reducing costs, improving supply chain efficiency, and providing industry training will further support widespread implementation.

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