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Risk Analysis and Mitigation in PEB Warehouse Construction Projects: A Case Study Approach

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Abstract - *With unique advances in structural capacity, expediency of construction and minimal cost, pre-engineered buildings (PEBs) have brought about a revolution in the warehouse market across India. Although these merits, the prospects have involved of the risk concerns in the PEB warehouse project which may result in the negative impact on the cost, duration and quality of the project completion. In this paper, the kinds of risk factors, their effects and the preventive actions of PEB warehouse construction are examined empirically. A detailed mixed-methods methodology was used combining literature review, practical and international case studies plus online questionnaires towards industry practitioners. Matrix was used for identification, classification, and prioritization of risks, as well as measures for the mitigation of potential risks. Results show that failure of the equipment, delay in procurement, lack of manpower resource and lack of financial planning are major challenges faced. The pragmatic suggestions outlined in this study will serve as a useful tool for PM, engineers and policymakers to enhance risk management strategies suitable for Indian PEB construction practices.*

Key Words: PEB, Risk Management, Prefabricated Construction, Warehouse, Mitigation Strategies, Construction Project Management.

1.INTRODUCTION

Pre-engineered buildings (PEBs) with the features of cheaper cost, flexible design, and fast construction is increasingly being used in warehouse building applications. Being similar to any other construction work, PEB warehouses are exposed to various types of risks in terms of design risk, material procurement delays, labour shortage, site level risks, productivity inefficiencies. These risks however are compounded in the Indian construction sector by peculiar logistical, financial, and legal challenges which are found especially in major cities like Chennai.

1.1 Aim

To holistically investigate the risks, to assess their significance, and to generate risk mitigation strategies for evaluating and improving risk-management systems for PEB warehouse construction.

1.2 Objectives

- Identify and categorize important risk items concrete PEB warehouse construction projects. Assess these risks and how they will impact the budget, time schedule, quality and safety.
- Examine current risk mitigation strategies and suggest more effective new ones.
- Offer practical guidelines to players in the construction industry for risk ranking.

1.3 Methodology

- Literature review on PEB risk mitigation.
- Journal Paper: Analysis of research on labor, cost, delay, and structural safety risks of PEB projects.
- Case Study Analysis: A detailed analysis of PEB warehouse buildings in India and abroad.
- Questionnaire Survey: The sample size for the structured questionnaire was 50 SK professionals including project managers, engineers, architects, and site officers.
- Statistical Analysis: Risk Index calculation, Pearson Correlation, Cronbach's Alpha to evaluate reliability.
- Risk Matrix: A tool assessing risk in terms of probability and impact, combining: qualitative and quantitative factors.

2. LITERATURE REVIEW

Pre-engineered building (PEB) is a modern concept of utilizing sustainable steel structures and can be compared with conventional steel building (CSB) which is analogous to compare wooden furniture with light wooden furniture. They are lighter (10–20% less) and quicker to erect (usually 6–8 weeks) because they are fabricated from prefabricated, tapered sections which are bolted together on-site. By comparison, CSBs take 20–26 weeks to be manufactured, involve considerable in-situ fabrication and are reliant on the use of hot-rolled sections. PEBs also enjoy the advantages of single-source responsibility that reduces coordination errors, provides for easier expansion, and is

more earthquake and wind resistant. Because of these benefits, PEBs are preferred for the construction of warehouses, especially in the fast-growing cities such as Chennai.

2.1 Identified Risks

The identified risks are listed in Table-1 below:

Table -1: Identified Risks.

Project Stage	Risk Type
Pre-Design stage	Economic Risks
	Financial Risks
	Policy and Regulatory Risks
	Administrative/Procedural Risks
	Market/Strategic Risks
	Human Resource Risks
	Planning Risks
Design Stage	Design Risks
	Technology Risks
	Coordination and Management Risks
	Regulatory and Standards Risks
	Schedule and Planning Risks
Procurement and Manufacturing stage	Supply Chain Risks
Construction Stage	Project Management Risks
	Labour and Workforce Risks
	Financial Risks
	Contractual Risks
	Communication and Coordination Risks
	Mechanical and Equipment Risks
Operation & Maintenance	Facility Management Risks
	Responsibility and Coordination Risks
	Design and Engineering Risks
	Quality Control Risks
	Structural Risks
	Environmental Load Risks
Environmental	Transportation Risks
	Logistics and Customs Risks
	Weather-Related Risks
	Force Majeure Risks
	Site Visibility and Safety Risks

3. CASE STUDIES

3.1 Global Case Studies

The DHL Warehouse in the Czech Republic was delayed by and ran over budget due to the pandemic. Contingency budgeting, remote communication tools and scenario planning were adopted to respond to these challenges.

Thai Union Facility, in Thailand, the following inclusion criteria were performed: ultrasonic testing in compliance with AWS D1. 1 standard, confirmation of the coating thickness was used to manage weld defects and keep a high coating quality.

In Malaysia, Sime Darby's risk management focused on lifting operations and exposure to radiation. The practices ranged from drone technology, to automatic welding and thermal personal protective equipment being used.

3.2 Indian Case Studies

Myntra FC, Karnataka: mechanical breakdown and life safety issues were often found while hoisting & rafter erection. There was significant emphasis on PPE, flagmen deployment and safety of the crane operation.

Shree Renuka Sugars Warehouse: Manual loading was substituted with mechanical loading which helped in reducing the hazard scores. Ergonomic equipment was also used, and the rules of the PPE were strictly applied.

GFC Warehouse, Chennai: Financial irregularities, shortage of trained labor force and poor site management led to extensive delays. Suggested remedial action includes improving communication, scheduling audits, and coordinating better with subcontractors.

4. RESULTS

A survey of 50 experts' attitudes was analyzed. Cronbach's Alpha values higher than 0.7 indicate good internal consistency. A complete risk matrix was created by placing the risks according to their likelihood and impact.

Table -2: Risk Matrix

Sl. No	Pre-Design Stage Risks	Risk Index	
1	Economic Risks	21.62	High
2	Planning Risks	15.12	High
3	Human Resource Risks	12.21	Moderate
4	Financial Risks	10.85	Moderate
5	Policy and Regulatory Risks	7.56	Moderate

6	Administrative/Procedural Risks	5.75	Low
7	Market/Strategic Risks	5.75	Low

Sl. No	Design Stage Risks	Risk Index	
1	Design Risks	22.09	High
2	Coordination and Management Risks	19.8	High
3	Schedule and Planning Risks	19.74	High
4	Regulatory and Standards Risks	12.96	Moderate
5	Economic Risks	9.52	Moderate
6	Technology Risks	6.25	Low

Sl. No	Procurement and Manufacturing Stage Risks	Risk Index	
1	Quality Defects	23.04	High
2	Lead Time and Delivery	22.08	High
3	Delivery Issues	12.21	Moderate
4	Identification issues	11.88	Moderate
5	Transportation Risks	6.5	Low
6	Natural Risks	3.15	Low

Sl. No	Construction Stage Risks	Risk Index	
1	Project Management Risks	21.62	High
2	Labor and Workforce Risks	19.8	High
3	Contractual Risks	18.48	High
4	Financial Risks	14.06	Moderate
5	Communication and Coordination Risks	12.58	Moderate
6	Safety and Health Risks	11.1	Moderate
7	Mechanical and Equipment Risks	3	Low

Sl. No	Operation and Maintenance Stage Risks	Risk Index	
1	Facility Management Risks	22.56	High
2	Design and Engineering Risks	13.68	Moderate
3	Responsibility and Coordination Risks	12.96	Moderate
4	Quality Control Risks	2.8	Low
5	Structural Risks	2.72	Low
6	Environmental Load Risks	1.82	Low

Sl. No	Environmental Risks	Risk Index	
1	Weather-Related Risks	22.09	High
2	Transportation Risks	5.2	Low
3	Logistics and Customs Risks	2.7	Low
4	Force Majeure Risks	4.2	Low
5	Site Visibility and Safety Risks	2.21	Low

5. DISCUSSION AND IMPLICATIONS

5.1 Mitigation Strategies:

- Proactive Risk Assessment: Make DPR risk and design risk identification an upfront process.
- Resource Utilization: BIM, CostX and MS ProjectUse of tools to see the project and predict outcomes.
- Education Programs: Offer at site and on-line training on safety, equipment maintenance, and use.
- Budgeting tactics: Save up a cushion, pay agencies at milestones, and audit.
- Vendor Risk Management: Define quality measures and initial sourcing mechanisms.

5.2 Practical Implications

- Raised productivity and resource management that is smarter.
- Shortened lead times thanks to simplified sourcing and logistics.
- Improved budgeting via tracking in real time and forecast accuracy.

6. CONCLUSIONS

It develops holistic, systematic and step-by- step procedures for identification and prioritization of the hazards in all stages of PEB warehouse construction projects. Major risks were identified at each stage: during the pre-design stage, economic and scheduling risks were considered to be the most important criteria for evaluating the feasibility and scope of the project; during the design stage, coordination and consistency risks were identified as significant problems causing delays and rework; in the procurement and in the

manufacturing stages, material lead times and material quality risks were found as major concerns affecting project schedules and the final quality of the result. At the same time, the operations and maintenance phases identified an effective facility management as a critical factor in maintaining long-term operational productivity, and the construction phase underscored labor shortages, disputes on contract terms and project management shortcomings as the most significant factors for delays and cost overrun. Although less so, the environmental hazards had been realized for their unpredictable behavior and consequent unanticipated interruptions to the project.

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