CHAPTER 41

Analysis on Environmental Risk Allocation and Delay Patterns in Indian Real Estate Construction Industry

Pradnya Hase, Vishakha Akhade**, Sudhanshu Sharma** and Sumit Patil****

ABSTRACT

Environmental risks have become a major cause of project delays in India's real estate construction sector, especially in rapidly urbanizing cities like Pune. The extreme rainfall, soil erosion, pollution, and delays in the granting of environmental clearances are some of the factors that greatly influence the project schedules and expenses. Although these risks have increasingly become a problem, they are usually underestimated and they are not properly distributed among the project stakeholders, resulting in conflicts, inefficiency and cost overruns. The purpose of the study is to examine allocation of environmental risks and how these impacts on delays in the real estate construction sector in Pune and also to create a full-fledged Environmental Risk Assessment Model (ERAM) to facilitate a positive and fair risk management. The mixed-method research strategy was taken, and it included literature review, interviews with experts, and a questionnaire survey in the form of a structured questionnaire. The analysis of data was done with the help of a relative grading which ranked major environmental risks. The suggested ERAM model can be used to quantitatively assess the probability and effects of environmental risks with the assistance of weighted scoring and a color-coded scoring matrix by determining high-risk areas in the initial planning of projects. Its applicability and reliability in enhancing coordination and the incidences of delays was verified by using a real project at Pune. The paper outlines how structured environmental risk assessment should be incorporated in the construction process to encourage sustainable construction, reduce conflict and improve efficiency in the entire project within the Indian real estate industry.

Keywords : Environmental Risk Assessment, Risk Allocation, Construction Delays, Real Estate Construction, Indian Construction Industry.

1.0 Introduction

The real estate construction industry is a major aspect of economic growth and fast urbanization of India.

**Corresponding author; Student, School of Construction, NICMAR University, Pune, Maharashtra, India (E-mail: p24700194@student.nicmar.ac.in)*

***Student, School of Construction, NICMAR University, Pune, Maharashtra, India*
(E-mail: p24700631@student.nicmar.ac.in; p24700206@student.nicmar.ac.in)

****Assistant Professor, School of Construction, NICMAR University, Pune, Maharashtra, India*
(E-mail: sumit.patil@pune.nicmar.ac.in)

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As significant as it may be, construction projects are usually subject to delays. Recent researches indicate that such delays are being more influenced by hazards of the environment due to urban development, climate change, and tightening of environmental regulations. The weather conditions such as heavy rain and improper waste disposal have direct influence on the productivity of construction, schedule of the project, and the success of a project. The past studies of construction management point to risk allocation as the determining factor of project success. Numerous researches have been conducted on the reasons why constructions are late and proposed risk-sharing strategies. Nevertheless, the majority of the environmental risk assessment models in literature are founded on the international setting. Such models usually fail to consider local climate, rules, and traditions of the Indian construction industry. As such, the environmental risk management of the Indian construction projects is primarily reactive. It results in conflicts, increased expenses and time wastage. Environmental risks are not given much attention in the planning of the projects in the Indian construction sector and are not addressed appropriately in the contracts. In the absence of defined procedures of determining, evaluating, and allocating environmental risks, the project stakeholders are at a loss. The resulting discrepancy in formal environmental risk management causes clashes, inflated costs on the project and delays.

The aims of this study are:

- To identify key environmental risks impacting real estate construction projects in India
- To assess and rank environmental risk factors that cause project delays
- To create an environmental risk assessment and allocation framework tailored for the Indian construction context

The research contributes to the existing literature because it addresses the deficiency of India-specific environment risk assessment models in the real estate construction industry. The suggested model promotes more proactive environmental risk management and more effective allocation of risks among the stakeholders. The results are supposed to assist project managers, developers, and policymakers to become more precise in planning, reduce conflicts, minimize delays, and enhance sustainability and performance of real estate construction projects in India.

2.0 Literature Review

Significant expansion has been experienced by India real estate building sector due to urbanization, deregulation, and rising housing demand. But with such growth, the uncertainties of the environment also tend to impact such projects with significant delays. Though numerous studies on project delay in the real estate construction sector exist, its identification within the context of the environment is still unexplored.

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It is recognized by existing research that some environmental factors like uneven rainfall patterns, temperature variations, pollution-related stoppages, soil and groundwater profiles, delays for clearance from authorities, among other factors, can impede the process of construction and cause increased expenditures. Kumar et al. (2021) as well as Rathi and Menon (2020) pointed out that project managers often fail to rely on facts for estimating environmental risk prior to the start of construction on a project; rather, they depend on their intuition alone.

One of the issues that generally keeps coming up in the literature is that of the lack of a standardized risk assessment model that suits the environment of the Indian construction industry. Most models tend to be generic in nature, designed on the principles of international models, but not applicable in their context. Thus, the risk of the environment is not consistently assessed and managed.

This is made worse by contract uncertainties. As found by some researchers, environmental risks fall vaguely under "force majeure" contracts, failing to make a distinction between predictable and unpredictable risks, Patil & Desai, 2021 #42; Natarajan & Ramesh, 2019 #24. These ambiguous allocations of risks tend to result in contract disputes if there are project delays on account of pollution control, groundwater, or government interventions.

Another significant restriction is posed by the low level of environmental risk awareness among all the projects numerous stakeholders. Environmental compliance is frequently regarded by construction professionals as an external regulatory burden has rather than an essential component of a project management is general. This view encourages a reactive strategy such as the beginning of work before the required environmental approvals are obtained, which leads to more penalties and stoppages.

A variety of tools have been recommended by several authors to address the issues mentioned above. Purpose of visually identifying and ranking location-specific hazards, ERM matrices have been proposed (Rathi & Menon,2020; Thakuret al.,2021). System based on fuzzy logic have also been investigated for the equitable distribution of environmental risk in contracts (Natarajan & Ramesh,2019; Naik & Reddy,2022). It has been suggested that historical delay databases be established, which would enable buffer allocation and anticipatory based on previous environmental disruptions (Joshi & Banerjee,2021).

Notwithstanding this contribution to the field, the literature currently in publication emphasizes the necessity of creating an integrated or comprehensive Environmental Risk Assessment Model (ERAM) that covers the elements of regulatory body monitoring, contractual risk factor allocation, overall stakeholder responsibility, and the application of data- driven analysis for delay prediction. In aspect, the current literature is woefully inadequate.

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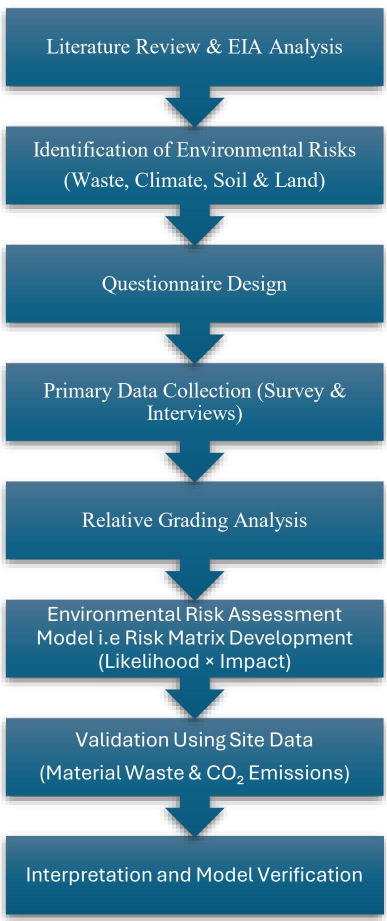
3.0 Research Methodology

3.1 Research methodology overview

To assess the environmental risk connected to real estate construction project, a mixed-method study methodology that integrated expert opinion with quantitative analysis tools was used by the current study. The study adopted this research study approach for the obvious reasons that environmental risks are not one-dimensional or straightforward and require both professional judgment and quantifiable analysis. The study approach was carefully designed to select risks systematically, prioritize risks objectively through numerical analysis, develop ERAM, and validate ERAM based on real-world project data.

Figure 1: Research methodology



Source: Created by authors

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The research methodology utilized three broad phases that corresponded to the research themes:

- Identification and classification of environmental risks
- Development of the Environmental Risk Assessment Model
- Validation of the model using site-based quantitative analysis

This modular format helped in ensuring clarity, traceability, and the applicability of results.

3.2 Identification and classification of Environmental Hazards

The identification and classification of the environment hazards represented the first step in the methodology of the research. It was an identification process of the environment factors which might have negative impacts on the construction activities of the real estate by causing delays in the activities of the construction process. The definition of environment hazards in the context of the research was seen as those of a natural environment and the operational environment.

The identification of environmental hazards was done by a thorough examination of peer-reviewed literature, reports of Environmental Impact Assessment of real estate projects, and environmental laws and policies of India. The secondary data examination was further followed by informal discussions with professionals in the field of construction, that is, site engineers and project managers, relating to local site conditions and new challenges concerning environmental issues of Pune. The inclusion of data from literature and expert inputs allowed covering different dimensions of environmental hazards, that is, theoretical and practical knowledge.

Using this collected data, some of the identified hazards were grouped into three main categories, which were climate-related hazards, soil and land degradation hazards, and finally, hazards under waste management. The hazards that were under waste management included material wastage during concreting and finishing, on-site improper segregation of construction and demolition waste, low recyclability of construction and demolition wastes, and improper disposal of construction and demolition wastes. On the other hand, climate-related hazards included high temperatures that affect productivity, rainfall intensity, high water demands for curing, and water availability during peak construction periods. Finally, soil and land degradation hazards included poor soil testing, land damage during excavation, soil erosion, soil drainage, and delays in construction that happen when soil conditions are improper.

3.3 Data collection procedure

The data collection procedure was designed to obtain reliable and representative information on environmental risks affecting real estate construction projects. A combination

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of both primary and secondary data was used to cover comprehensively, as well as to achieve methodological triangulation. The primary focus is of data collecting was placed on actual building methods, professional experiences, and environmental issues at the site level that are pertinent to the real estate industry in Pune.

A systematic questionnaire survey was employed to collect primary data from construction professional involved in the project planning, implementation & monitoring. The questionnaire covered mainly three environmental criteria of waste management, climate related issues & soil and land degradation, which were developed based on information gathered during the environmental risk identification step. To make question easier to answer and to allow for quantitative analysis through percentage-based evaluation, they were designed as multiple choice question. In addition to the survey questionnaire, informal conversation was held with project managers and site engineers to verify survey answer and acquire a contextual grasp of site procedures.

The target audience would be made up of site engineers with at least three years of experience, project managers, planning engineers, safety managers, assistant general manager and other department of billing, quality, MEP and design. The section of this category would have been based on their involvement in the building process. Given the scale and nature of the investigation, it is anticipated that the complete population would be made up of 50 specialists. To accomplish efficient distribution and response tracking, data gathering was accomplished using Google Forms. A total of 49 responses were collected from the total population, which made a response rate of 98 percent. The responses were then exported from Google Forms to Microsoft Excel for data coding and analysis purposes. Using an estimated finite population, the finite population correction formula was used for assessing the appropriateness of the size of the sample collected for solving this research problem. The minimum required sample size was estimated at 44, and it was surpassed, making the data collected statistically reliable.

The secondary data collection regarding supporting primary data, as well as serving as theoretical background for conducting research, occurred simultaneously. In this case, secondary data took forms of peer-reviewed journal publications, Environmental Impact Assessment reports, government environmental regulations, construction industry guidelines, as well as emission factor publications. These secondary data sources aided research on risks associated with the environment, aided in preparing risks models, as well as provided industry-standard coefficients necessary to perform validity calculations.

3.4 Development of Environmental Risk Assessment Model (ERAM)

This stage entailed the development of an Environmental Risk Assessment Model (ERAM) for assessing and prioritizing the various identified environment-related risks. This

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was meant to ensure the transformation of the qualitative results of the surveys into quantitative results for comparison purposes.

Both of the analytical techniques that were utilized in the formulation of the proposed model are briefly defined below:

- *Relative grading method:* The relative grading system was employed to equalize the survey questionnaires' results from the respondents' questionnaires. The system was able to quantify risks associated with different categories using a common score system (scores from 1 to 5). The relative grading system aided in ranking the risks associated with the environment based on their level of severity and occurrence.
- *Risk Matrix method:* A Risk Assessment Matrix has been developed by integrating the relative grading results of the likelihood of occurrence and severity of impact. The Risk Assessment Matrix categorizes environmental risks as low, medium, and high-risk environments. The risk assessment matrix allows a clear prioritization of risks and identification of important environmental issues that demand attention at any given instance of time.

3.5 Validation of the environmental risk assessment model

The Environmental Risk Assessment Model developed from this study was validated to evaluate the practicability as well as the reliability of the model, considering real-time conditions in the construction process. The model was applied to a real estate project at Pune, the state of Maharashtra. A quantitative validation methodology was employed where risk rankings were compared against site material use data. Key materials in the construction process, including cement, concrete, steel, and construction & Demolition waste, were taken for validation since they are contributors of a certain degree of risk on the environment during the process of construction. The validation process consisted of calculations regarding material loss and the resultant effect on the environment in terms of carbon dioxide release, based on emission factors presented in existing environmental literature. This helped in determining whether high-priority environmental risks, which appeared in the risk matrix, actually led to increased material loss and associated environmental effects.

The results from the validation are then compared with actual practices on-site as well as with experts' opinion as a measure of accuracy and relevance of the technique offered by the model produced. All computations, factors, assumptions, as well as the validation results, are discussed extensively within the chapter on Data Analysis.

4.0 Data Analysis

This phase of the study gives a comprehensive description of the data analysis of the results obtained from the questionnaire survey and observations.

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The data analysis is aimed at measuring, ranking, and analysing the environmental risks related to real estate construction projects in a scientific and objective manner. This is done by analysing the surveys through relative grading, risk matrix and quantitative validation methodology to facilitate the transformation of the questionnaire survey into a practical risk measure, using which the key environmental factors can be identified and the Environmental Risk Assessment Model can be verified through empirical calculations.

4.1 Survey design and relative grading approach

The survey designed was structured in a manner of answering the three parameters in a series of multiple choices answers that were designed to quantify and collect qualitative data. The results were then provided in percentages and the relativistic grading scale was calculated as in the equation below.

$$Scale_i = \left(\frac{\%i}{\%\{max\}}\right) \times 5$$

Where:

- $Scale_i$: The relative scale for response category i.
- $\%i$: The percentage of responses for category i.
- $\%\{max\}$: The highest percentage among all categories for that question.

Data can be normalized using the formula on a scale of 1-5 with 5 being the level of greatest prevailed or critical response/importance, and lower scores reflecting less importance. The terms used below comprise:

- Percentage of Responses (%): This is a percentage representation of survey respondents who filled in a particular category in the survey and shows its prevalence.
- Implication: Recommendation based on the scaled responses that would be used to work towards risk reduction.

4.2 Environmental risk assessment model

A risk matrix has been developed to integrate survey data, assigning the likelihood based on response percentages:

- 0–20%: 1 (Very Low)
- 21–40%: 2 (Low)
- 41–60%: 3 (Medium)
- 61–80%: 4 (High)
- 81–100%: 5 (Very High)

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Table 1: Risk Matrix

Impact	5.00	5.00	10.00	15.00	20.00	25.00
	4.00	4.00	8.00	12.00	16.00	20.00
	3.00	3.00	6.00	9.00	12.00	15.00
	2.00	2.00	4.00	6.00	8.00	10.00
	1.00	1.00	2.00	3.00	4.00	5.00
		1.00	2.00	3.00	4.00	5.00
		Likelihood				

Source: Created by authors

Impact has been taken directly from the relative scales (1–5). Risk score was calculated as:

$$RiskScore = Likelihood\ X\ Impact\ (Scale)$$

Risk levels had been categorized:

- 1–5: Low (Green)
- 6–14: Medium (Yellow)
- 15–25: High (Red)

For example:

- Waste (Concreting): 60% (Likelihood = 3), Scale = 5 → Risk Score = 15 (High)
- Climate (Concrete Curing): 68% (Likelihood = 4), Scale = 5 → Risk Score = 20 (High)
- Soil (Yes Testing): 86% (Likelihood = 5), Scale = 5 → Risk Score = 25 (High)

This matrix identifies high-risk areas (like waste from concreting, water for curing etc) for targeted interventions.

4.3 Validation model

In order to justify the survey results, a quantitative model was created on the key materials (cement, concrete, steel, construction and demolition waste). The inputs comprise number of quantities required, wastage (mean wastage of survey averages e.g. 5 percent for cement on basis of questionnaire survey), amount of wasted and resulting CO2 emissions in terms of standard factors:

$$\text{Quantity wasted} = \text{Total quantity} \times \%\ \text{wasted}$$

$$\text{CO2 Released} = \text{Quantity wasted} \times \text{emission factor}$$

Emission factors (from literature, e.g., IPCC guidelines):

- Cement: 0.9 t CO_2/t (chemical process).
- Concrete: 0.3 t CO_2/m^3 (production impacts).
- Steel: 1.9 t CO_2/t (energy-intensive).
- C&D Waste: 0.18 kg CO_2/kg (replacement emissions).

Example Calculation (for 10 t cement, 5% wasted):

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- Wasted = 10 × 0.05 = 0.5 t
- CO_2 = 0.5 × 0.9 = 0.45 t

The calculation of the wasted quantity for each material was performed, by multiplying the total required quantity with the percentage of wastage. Standard emission factors, which are found in literature and IPCC guidelines, were then used to calculate the carbon dioxide emissions. The site-level emissions were determined individually per material but were added together. Cement and concrete were the greatest contributor in the analysis because it has greater emission factors and volumes of use; steel also contributed a lot although it is used in smaller volumes because it is an energy-intensive manufacturing process.

The three-site analysis enabled the comparison in the validation framework. Although the rate of wastage was the same, the amount of material that gets wasted, and the rate of CO2 emission was different in the three sites due to the difference in the project size and material consumption at the respective project sites. The comparative analytical study showed that the volume is directly linked to the environmental impact, which confirms the sensitivity of the validation model to actual project data. At the same time, it also discovered that the pattern of material contribution to the emissions was similar in all the three sites, which determined the strength of the model.

Such an integrated solution offers a well-developed framework of evaluation and reduction of environmental hazards during construction as part of the sustainable development targets. The model may be extended to site-specific data to do dynamic simulations in the future.

5.0 Results

The Environmental Risk Assessment Model was validated using real data of material quantity in three construction sites in real estate development. The model is validated by the estimation of material wastage and equal CO2 emission to warrant its feasibility at a construction site. All sites were assumed to have the same waste percentages and the same emission factors in order to maintain consistency.

Site 1 (Manaroma Heights) was the most impactful regarding the environment due to its comparatively larger size of construction, which took around 803 tonnes of cement, 1603.2 m3 of concrete, and 160 tonnes of steel, which corresponds to about 75.4 tonnes of CO2 wastages. Site 2 (Uptown Bay), in its turn, had moderate levels of environmental impacts, as the material usage was 401 tonnes of cement, 877.2 m3 of concrete, 87.7 tonnes of steel, thereby causing approximately 39.5 tonnes of wastages of CO2. Site 3 was the least affected, with the total wastages of approximately 23.5 tonnes of CO2, given the rather small

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construction activity. It is worth noting that although absolute measures of wastages may vary, sighting between all three construction sites indicates consistency in view of similar trends of environmental risks particularly material wastages with regard to concrete works.

Considering the general findings of the comparative analysis of the three sites, the dependencies between the scale of the project and the environment impact are also clear as bigger projects have demonstrated bigger emissions because of the same percentage of waste. This shows that the model is valid because the ranking of risks according to the risk matrix remains accurate in the calculation of the emissions in terms of the amount of CO_2 produced. This validates the model's efficiency as a decision support tool for the mitigation of environmental risks in real estate industry of differing scales.

6.0 Conclusion

This study is dedicated to the Pune area and is associated with the allocation of environmental risks in the context of the delay related to the construction projects in the real estate business. It determines and evaluates the major environmental risks in waste management, climate data, soil and land degradation using a mixed-method, which involves stakeholder surveys, relative grading, risk matrix evaluation, and quantitative validation model. The findings indicated that waste production during concreting and ineffective management of materials was the most pertinent environmental risk factors that affected performance of the project.

One of the strong points of the Environmental Risk Assessment Model created in the current work is the possibility to transform the qualitative notion of the risk perception into the quantitative one and into the environmental impact. This very model, when put to test of its effectiveness on the basis of the data gained at three distinct construction sites aptly demonstrated that larger projects could contribute to a multiplication of the environmental impact, regardless of the wastage.

To sum up, this paper provides a practical and methodical solution to environmental risk identification, consideration, and reduction in real-estate development. The strategy can be relevant in assisting the parties involved in the development to optimize the environmental and waste effects in development and also play a part in sustainable development practices.

7.0 Recommendations

Future research should expand this model to a broader range of materials, including cement, concrete, steel, construction and demolition waste, focusing on the efficiency of recycling and the impact on landfills. Further research into soil and land degradation should

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be carried out in the areas of excavation practice, erosion control, and land restoration after construction. Temperature fluctuation, rainfall intensity, and water scarcity are a few more climate-related risks to take into account, using both long-term and site-specific data. These might be integrated into digital planning and monitoring tools, allowing for the further improvement of environmental risk management in real estate construction.

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