Evaluating Critical Factors Affecting Safety Management in Construction Projects

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Abstract

The construction industry in India, a significant contributor to economic growth, faces persistent safety challenges due to complex project dynamics and inadequate safety protocols. This study evaluates the effectiveness of safety management prac- tices, identifies critical factors influencing safety performance, and proposes a prac- tical implementation framework for construction projects. A questionnaire survey was conducted among 85 respondents from construction firms in Hyderabad, India, using a five-point Likert scale. Data were analyzed using SPSS v27, employing de- scriptive statistics, Relative Importance Index (RII), and factor analysis. Findings highlight that corrosive chemicals (RII = 85.3)

Keywords: Construction safety, Safety management, Relative Importance Index, Factor analysis, Accident prevention, India

1 Introduction

The construction industry is a cornerstone of India's economic and social development, contributing approximately 8% to the GDP of developing nations and employing over 100 million workers globally [14]. However, the sector is notorious for its high accident rates, with an estimated 350,000 fatal accidents annually across industrial and construction sectors worldwide [15]. In India, factors such as transient workforce dynamics, inade- quate supervision, and regulatory gaps exacerbate safety risks [16]. The transient nature of construction projects, coupled with diverse hiring practices and financial pressures, creates unique challenges compared to stable environments like manufacturing [17].

This study addresses three primary objectives: (1) evaluating the effectiveness of safety management practices, (2) identifying critical factors influencing safety, and (3) propos- ing a framework for implementing safety management in construction projects. Specific research objectives include investigating current safety protocols, identifying accident causes, assessing the effectiveness of safety measures, examining the impact of training, and evaluating management commitment. Conducted in Hyderabad, India, a hub for con- struction activities, this study focuses on management, environmental, and operational factors affecting safety.

The significance of this research lies in its potential to enhance worker safety, reduce project delays, and improve industry standards in a rapidly growing market. The paper is organized as follows: Section 2 reviews relevant literature, Section 3 details the method- ology, Section 4 presents results, Section 5 discusses findings, Section 6 offers conclusions and recommendations, and Section 7 lists references.

2 Literature Review

2.1 Background

Safety management in construction has evolved significantly since the 19th century, when workplace accidents prompted early interventions like insurance and wage adjustments for high-risk jobs [19]. The establishment of the National Occupational Research Agenda in 1996 marked a shift toward systematic research to mitigate occupational risks [18].

2.2 Recent Studies

Recent studies emphasize behavioral, technological, and organizational interventions. (author?) [1] found that a positive safety culture, driven by continuous training and management commitment, significantly reduces accident rates. (author?) [2] explored technological interventions, such as wearable sensors and AI-based hazard detection, noting improved hazard identification but highlighting barriers like cost and resistance to change. (author?) [3] demonstrated that structured safety training enhances compliance, recommending regular refresher courses. (author?) [4] used structural equation modeling to show that leadership commitment directly influences safety climate and accident rates.

Internationally, (author?) [6] identified unskilled labor and inadequate precautions as key accident contributors in construction sites. (author?) [7] ranked 58 safety factors using RII and factor analysis, categorizing them into personal, management, environmental, and regulatory factors. (author?) [8] extracted 18 critical factors, grouped into management attitudes, work environment, worker safety, and prevention measures. (author?) [9] highlighted technical challenges in megaprojects, such as improper equipment placement leading to fatalities. (author?) [10] underscored the role of safety audits in minimizing accidents, while (author?) [11] advocated for Building Information Modeling (BIM) to enhance safety data management.

2.3 Research Gaps

Despite advancements, gaps persist, including inconsistent accident reporting in devel- oping countries [12] and a lack of integrated safety management systems. This study addresses these gaps by focusing on the Indian context, using empirical data to validate critical factors and propose actionable frameworks.

3 Methodology

3.1 Research Design

This quantitative study employed a questionnaire survey to collect primary data from construction professionals in Hyderabad, India. Factors affecting safety were identi- fied through an extensive literature review and site observations, categorized into 11 groups: management-related, fire hazards, housekeeping, organizational hazards, unsafe equipment, improper ventilation, improper lighting, machine accidents, chemical hazards, falling from heights, and supervision/training (Table 1).

A five-point Likert scale (1 = Very Low, 5 = Very High) was used to assess factor importance. The questionnaire was validated by field experts and distributed to 85 respondents, including engineers, contractors, and workers. Secondary data were sourced from industry reports and prior studies.

Table 1: Classification of Safety Factors

Category	Examples
Management-Related	Insufficient experienced managers, lack of first aid Fire Hazards Ignition sources, flammable liquids
Housekeeping	Slips/trips, disordered storage Organizational Hazards Poor worker-management relations Unsafe Equipment Defective scaffolds, cranes Improper Ventilation Mold growth, poor air quality Improper Lighting Glare, insufficient illumination Machine Accidents Insecure lifting, equipment failures Chemical Hazards Toxic, corrosive substances
Falling from Heights	Inadequate fall protection Supervision/Training Inadequate training, poor supervision

3.2 Data Collection

Primary data were collected from 85 respondents across construction firms in Hyderabad, with 80 valid responses (94% response rate). The questionnaire covered demographic details and safety factor ratings. Secondary data included academic journals, industry reports, and websites.

3.3 Data Analysis

Data were analyzed using SPSS v27. Techniques included:

- Descriptive Statistics: For demographic profiles and response frequencies.
- Relative Importance Index (RII): Calculated as $RII = \frac{\sum W}{A \times N}$, where W = weights, A = highest weight (5), N = number of respondents [13].
- Factor Analysis: Included Kaiser-Meyer-Olkin (KMO) test, Bartlett's test, com- munalities, total variance explained, scree plot, and rotated component matrix.
- Reliability Analysis: Cronbach's alpha was used to assess internal consistency (Ta- ble 2).

Table 2: Cronbach's Alpha Internal Consistency

Cronbach's Alpha	Internal Consistency
0.9+	Excellent
0.8–0.9	Good
0.7–0.8	Acceptable
0.6–0.7	Questionable
<0.6	Poor

Validity was ensured by aligning questions with research objectives and literature. Ethical considerations included informed consent and respondent anonymity.

4 Results

4.1 Demographic Profile

Of the 80 valid responses, 82% were male, and 18% were female.

<30 years (22%), 31–35 (18%), 36–40 (25%), 41–45 (15%), >45 (20%). Respondents had varied experience levels, from 1–5 years to >20 years, representing diverse roles (engineers, contractors, workers).

4.2 Descriptive Analysis

Response frequencies for each factor category were tabulated (e.g., Tables 4.1.3–4.1.13 in the original dissertation). For instance, poor housekeeping causing injuries received 34 ”Strongly Agree” responses (42.5%), indicating significant concern.

Age distribution:

4.3 Relative Importance Index (RII)

The RII ranked factors by perceived importance (Table 3). Top factors included:

- Corrosive chemicals (RII = 85.3%)
- Safety poster display (RII = 84.8%)
- Improper electrical equipment (RII = 83.6%)

The lowest-ranked factor was surrounding environment pollution (RII = 46.9%).

Table 3: Ranking of Factors Based on RII (Top 10)

Rank	Factor	RII (%)
1	Corrosive chemicals	85.3
2	Safety poster display	84.8
3	Improper electrical equipment	83.6
4	Overloaded circuits	82.5
5	Inadequate training	81.0
6	Improper ventilation	80.3
7	Unsuitable PPE	79.5
8	Heavy equipment hazards	78.8
9	Disarranged site	77.5
10	Falling objects	76.3

4.4 Factor Analysis

The KMO measure was 0.603, indicating moderate sampling adequacy. Bartlett's test yielded $\chi^2 = 154.913$, $p < 0.001$, confirming significant correlations. Communalities ranged from 0.672 to 0.935, showing variable contributions to extracted components. The first principal component explained 12.616% of variance, with cumulative variance up to 32.741% for three components (Table 4). The scree plot suggested retaining 3– 4 factors. The rotated component matrix showed strong loadings (e.g., variable A1 = 0.812 on Component 1). The correlation matrix determinant (0.002) indicated potential multicollinearity, suggesting data preprocessing needs.

Table 4: Total Variance Explained (Excerpt)

Component	Initial Eigenvalues (%)	Cumulative (%)
1	12.616	12.616
2	10.250	22.866

3	9.875	32.741

5 Discussion

The high RII for corrosive chemicals (85.3%) aligns with (author?) [5], who identified chemical hazards as major contributors to equipment breakdowns and injuries. The emphasis on safety posters (84.8%) and electrical equipment (83.6%) reflects the need for visible safety communication and reliable infrastructure, corroborating (author?) [4]. Factor analysis results support (author?) [8], with strong interrelationships among man- agement, environmental, and worker-related factors.

The moderate KMO (0.603) suggests data limitations, possibly due to sample size or regional focus. Multicollinearity in the correlation matrix indicates overlapping factors, necessitating refined variable selection in future studies. Practical implications include adopting BIM for hazard identification [11] and implementing regular safety audits [10]. The study's focus on Hyderabad limits generalizability; national or cross-country studies could provide broader insights.

6 Conclusion and Recommendations

This study identified 25 critical factors affecting safety management in construction, with corrosive chemicals, inadequate training, and improper electrical equipment being the most significant. A proposed implementation framework includes:

- Establishing a comprehensive safety policy.
- Allocating resources for safety management.
- Identifying and prioritizing hazards.
- Implementing hazard control measures.
- Monitoring and updating safety systems.

Recommendations for effective safety management include:

- Mandatory safety training and refresher courses.
- Integration of technologies like BIM and AI for real-time monitoring.
- Enhanced management commitment through visible leadership.
- Regular safety audits and emergency preparedness plans.

Future research should explore cost-benefit analyses of safety interventions and expand to diverse geographical contexts to enhance generalizability.

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10 Conflicts of Interest

The authors declare no conflicts of interest.