International Research Journal on Advanced Engineering Hub (IRJAEH)
e ISSN: 2584-2137
Vol. 04 Issue: 05 May 2026
Page No: 2668-2675
https://irjaeh.com
https://doi.org/10.47392/IRJAEH.2026.0352

Assessment of Electrical Safety Risks In High- Rise Building Construction

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Abstract

Electrical accidents remain one of the leading causes of fatalities and injuries in high-rise construction projects, often resulting from unsafe practices, inadequate training, and failure to comply with safety regulations. This project aims to identify the root causes of electrical accidents in high-rise construction sites and propose effective prevention strategies to mitigate these risks. The research begins with a comprehensive review of relevant literature, safety standards (such as IS codes and OSHA regulations), and documented case studies to understand the nature and frequency of electrical hazards in vertical construction environments. Primary data is collected through structured interviews, site inspections, and surveys administered to electrical workers, site engineers, and safety officers across multiple ongoing high-rise construction projects. The study reveal that major causes of electrical accidents include improper use of temporary electrical installations, lack of personal protective equipment (PPE), poor maintenance of electrical tools and wiring, exposure to wet working conditions, and absence of lockout-tagout (LOTO) procedures. Human error and lack of awareness also contribute significantly to incident rates. Based on the findings, the study recommends practical safety interventions such as regular safety audits, mandatory training programs on electrical safety, implementation of site-specific electrical safety protocols, use of insulated tools, and proper grounding of temporary power systems. The study emphasizes the importance of safety culture and top-down commitment to hazard prevention in high-rise construction projects. This project contributes to the body of knowledge in construction safety by offering actionable insights and suggesting a framework for minimizing electrical risks in high-rise construction environments. The conclusions aim to support construction managers, safety professionals, and policymakers in developing safer working conditions for all stakeholders involved.

Keywords: *Electrical Accidents, High-Rise Construction Safety, Hazard Identification and Risk Assessment, Lockout-Tagout (LOTO), Electrical Safety Management.*

1. Introduction

High-rise building construction projects involve complex operations that depend heavily on temporary and permanent electrical systems. From tower cranes and hoists to lighting, welding machines, and power tools, electricity plays a vital role in maintaining productivity and project timelines. Improper installation, poor maintenance, and unsafe work practices significantly increase the risk of electrical accidents such as shocks, arc flash incidents, fires, and fatalities. The vertical nature of high-rise construction further intensifies these risks due to extended cable routing, exposure to environmental conditions, and frequent system modifications. Electrical safety management in construction must align with established safety standards such as those outlined by the Occupational Safety and Health Administration (OSHA) and relevant national

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electrical codes. Despite regulatory frameworks, accident statistics indicate that electrical hazards remain a major contributor to workplace injuries in construction sectors worldwide. This study focuses on assessing electrical safety risks in high-rise building construction through systematic hazard identification, risk analysis, and evaluation of control measures [1-3]. Analyzing temporary installations, personal protective equipment compliance, environmental factors, and human behavior, the assessment aims to identify critical risk areas and recommend structured interventions to enhance worker safety and project reliability.

2. Literature Review

Recent studies highlight the growing concern of electrical and fire-related hazards in high-rise construction. Mamatha N and Ajai Chandran C. K. (2025) examined fire behavior in electrical shafts of high-rise residential buildings in Bengaluru. Their findings showed that smoke accumulation and toxic gases significantly delayed evacuation (RSET > ASET), even with NBC-2016 provisions such as sprinklers and ventilation, emphasizing the need for improved compartmentalization and ventilation systems. Santipap Phudphong et al. (2025) developed a six-step accident prevention program for pipeline construction, demonstrating that behavioral and environmental interventions significantly reduce accidents. Similarly, A. Mahendran and R. Hari Haran (2025) stressed the effectiveness of checklist-based hazard identification and highlighted gaps in electrical safety training. Technology-driven solutions were explored by Jayasundara S. S. and Eranga B. A. I. (2025), who emphasized IoT-based monitoring for proactive safety management. Risk matrix applications by Om Prakash Giri et al. (2024) identified electrical hazards and live wiring as high-risk activities in high-rise projects. Earlier research, including Francis K. W. Wong et al. (2018), analyzed electrical and mechanical accident patterns, reinforcing the importance of targeted safety interventions. Collectively, literature confirms that electrical hazards in high-rise construction require integrated engineering controls, behavioral training, technological monitoring, and systematic risk assessment frameworks.

3. Methodology

High-rise building construction projects involve complex activities that rely heavily on electrical systems for powering equipment, lighting, and machinery. However, unsafe electrical installations, poor maintenance, and lack of worker awareness can lead to serious hazards such as electric shocks, arc flashes, fires, and fatalities. The vertical and dynamic nature of high-rise projects further increases exposure to risks due to temporary wiring, frequent modifications, and environmental conditions like rain and dust. Therefore, systematic assessment of electrical safety risks is essential. This study focuses on identifying hazards, evaluating risk levels, and recommending effective control measures to ensure safer construction environments shown in Figure 1.

Site Selection
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Data Collection
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Hazard Identification
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Risk Assessment
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Data Analysis
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Development of Control Measures
↓
Result and Discussion
↓
Conclusion

Figure 1 Methodology

3.1. Site Selection

Site selection is a foundational component in assessing electrical safety risks in high-rise building construction. The credibility, accuracy, and applicability of research findings depend significantly on choosing appropriate and representative construction projects. Since electrical hazards differ based on project size, construction phase, workforce strength, and management practices, a systematic selection strategy was adopted. One of the primary considerations was building height and project scale. High-rise structures involve complex vertical power distribution systems supplying electricity across multiple floors. This increases risks related to voltage drops, cable stress, and temporary wiring modifications. Large-scale projects also operate numerous electrical machines simultaneously, raising load demand and overloading probability. The stage of construction was another critical factor. Electrical hazards vary between structural, installation, and finishing phases. Structural stages involve heavy equipment and temporary wiring, while finishing stages include testing and energization risks. Selecting sites at different phases ensured comprehensive hazard coverage. Special attention was given to temporary electrical installations, as most construction-related electrical accidents originate from unsafe temporary systems. Projects with active distribution boards, portable equipment, and exposed cabling were prioritized. Workforce strength and skill level were evaluated to understand the role of human factors, supervision, and training in risk occurrence. Compliance with safety standards such as those prescribed by the Occupational Safety and Health Administration was reviewed to compare regulatory adherence levels. Environmental exposure, type of electrical equipment used, availability of safety management systems, and geographic conditions were also assessed. A purposive sampling strategy ensured relevant site selection. Proper site selection ultimately strengthened hazard identification accuracy and ensured that developed control measures were realistic and practically applicable to high-rise construction environments shown in Figure 1.

3.2.Data Collection

Data collection formed the core foundation of this research, ensuring accurate hazard identification and reliable risk assessment. Both primary and secondary data were collected from three active high-rise construction projects (G+20 to G+28 floors) over a 12-week period. A mixed-method approach combining quantitative measurements and qualitative inputs enhanced the validity of findings. The process included five major components: site profile analysis, structured questionnaire survey, safety inspections, accident record review (2023–2025), and technical electrical assessment. Workforce data showed 557 total workers, including 82 electrical workers directly exposed to electrical risks (14.7%). A structured questionnaire administered to 120 personnel yielded 110 valid responses (91.6% response rate). Results indicated safety gaps—47% lacked awareness of Lockout-Tagout (LOTO) procedures, and only 46% were aware of arc flash hazards. A total of 48 electrical safety inspections identified recurring deficiencies such as improper temporary wiring (31%), damaged insulation (21%), and absence of RCCB/ELCB protection (17%). PPE observations

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revealed low arc face shield compliance (42%). Accident analysis recorded 21 electrical incidents over three years, including 2 fatalities. The calculated incident rate was 37.7 per 1000 workers, indicating elevated exposure risk. Technical assessments further revealed overloaded panels and high earthing resistance, confirming systemic electrical safety deficiencies [4-6].

3.3. Hazard Identification

Hazard identification is a structured and analytical process used to recognize potential electrical hazards that may lead to electric shock, arc flash, fire, equipment damage, or fatal injuries in high-rise building construction. Due to vertical expansion, temporary power distribution, changing work environments, and multi-trade activities, electrical risks in high-rise projects are dynamic and complex. For this study, hazard identification was conducted across three high-rise construction sites (G+20 to G+28 floors) with a total workforce of 557 workers, including 82 electrical workers shown in Table 1.

Table 1 Temporary Electrical Installation Hazards (48 Inspections)

S.NO	Hazard	Frequency	Percentage
1	Improper temporary wiring	15	31%
2	Overloaded distribution boards	7	15%
3	No RCCB/ELCB installed	8	17%
4	Exposed cable joints	9	19%
5	Unsecured cable routing	11	23%

Table 2 Equipment-Related Hazards

Hazard	Frequency	Percentage
Damaged cable insulation	10	21%
Defective power tools	6	13%
Improper extension cord use	12	25%
Absence of tool inspection tags	14	29%

Table 3 Hazard Distribution by Category

Category	Number of Hazards	Percentage
Temporary Installation	9	31%
Equipment & Tools	7	24%
Grounding & Protection	5	17%
Environmental	4	14%
Behavioral & Administrative	4	14%

A systematic approach was adopted using 48 structured site inspections, Job Safety Analysis (JSA), review of three-year accident and near-miss records (21 incidents), worker questionnaire surveys (110 respondents), and technical electrical system assessments. A total of 29 significant electrical hazards were identified and categorized into five groups: temporary electrical installation hazards, equipment and tool hazards, grounding and protection system hazards, environmental hazards, and behavioral/administrative hazards. Statistical evaluation revealed that temporary wiring defects accounted for 31% of inspection findings and contributed to 34% of past accidents. Wet working conditions were observed in 44% of inspections, while 47% of workers lacked awareness of Lockout-Tagout (LOTO) procedures. Out of the identified hazards, 34% were classified as high-potential hazards capable of causing severe injury or fatality. The findings confirm that electrical risks are both technical and behavioral in nature, requiring

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systematic hazard elimination and strict safety management controls.

3.4. Risk Assessment

3.4.1. Introduction to Risk Assessment in Electrical Safety

Risk assessment is a systematic process used to evaluate identified hazards by determining their likelihood and severity, thereby prioritizing control measures. In high-rise building construction, electrical risk assessment is critical due to temporary installations, vertical power distribution, confined panel rooms, and continuously changing work conditions [7-10]. Electrical systems are frequently modified as floors increase, exposing cables and panels to dust, moisture, vibration, and mechanical damage. Workers operate at heights and often near energized systems, increasing the probability of electrocution, arc flash, and fire incidents. The objective of this assessment is to quantify electrical hazards using a structured 5 × 5 risk matrix and align findings with recognized safety frameworks such as the Occupational Safety and Health Administration guidelines and relevant Indian Standards (IS codes) which is briefly explained in the above given Tables 2,3 and 4.

Table 4 Risk Prioritization

S.No	Hazard	Risk Score	Risk Level
1	Improper temporary wiring	20	Extreme
2	No RCCB/ELCB	20	Extreme
3	Damaged insulation	16	Extreme
4	Wet conditions	16	Extreme
5	Overloaded DB	12	High
6	Improper earthing	15	High
7	No LOTO	15	High
8	Arc flash exposure	15	High
9	Defective tools	12	High

3.4.2. Risk Assessment Methodology

A hybrid qualitative–quantitative approach was adopted. Hazards identified through 48 inspections, worker interviews, and accident record analysis were evaluated using: Risk Score = Likelihood (L) × Severity (S) Likelihood was rated from 1 (Rare) to 5 (Almost Certain), and Severity from 1 (Minor Injury) to 5 (Fatality). Risk levels were categorized as Low (1–5), Medium (6–10), High (11–15), and Extreme (16–25). Findings showed that improper temporary wiring, absence of RCCB protection, damaged insulation, and wet conditions scored in the Extreme category (Risk Score 16–20). Overloaded panels, lack of LOTO, improper earthing, and arc flash exposure were categorized as High Risk (Score 12–15). The assessment confirms that temporary power management hazards contribute to nearly 60% of total risk exposure, emphasizing the urgent need for engineering controls, strict supervision, and continuous safety monitoring in high-rise construction projects [11-14].

3.5. Data Analysis

The data analysis phase was conducted to interpret inspection findings, quantify electrical risk levels, and identify statistically significant patterns across three high-rise construction sites. A total of 48 structured inspections were analyzed along with worker interviews, safety reports, and PPE compliance observations. Hazards were grouped into temporary installation defects, PPE compliance gaps, maintenance failures, and procedural deficiencies.

3.5.1. Temporary Electrical Installation Analysis

Temporary electrical installations emerged as the dominant hazard source. The statistical distribution showed: improper temporary wiring (31%), damaged cable insulation (21%), absence of RCCB/ELCB (17%), improper earthing (15%), overloaded distribution boards (15%), and lack of danger signage (16%). Improper wiring alone accounted for nearly one-third of unsafe observations, indicating systemic planning and supervision deficiencies. When combined with damaged insulation (21%), over 50% of recorded hazards were directly linked to poor cable management practices. The absence of RCCB protection (17%) further increases both likelihood and severity of shock incidents.

3.5.2. PPE Compliance Analysis

PPE compliance showed mixed performance: insulated gloves (68%), safety shoes (81%), arc face shield (42%), and rubber mats near panels (55%). The low arc flash shield compliance (42%) significantly elevates injury severity in case of electrical faults.

3.5.3. Risk Distribution and Trends

Risk matrix analysis revealed that approximately 40% of major hazards fall under the Extreme category. Cross-analysis indicated that sites with weak supervision showed higher wiring defects and lower PPE compliance. Environmental factors such as moisture and dust further amplified risks. Overall, the analysis confirms that temporary power systems, PPE gaps, and inadequate supervision are the primary drivers of electrical risk in high-rise construction.

3.6. Development of Control Measures

The development of control measures was based on findings from risk assessment and data analysis, where several hazards were categorized under High and Extreme risk levels. A structured mitigation strategy was formulated following the Hierarchy of Controls recommended by the Occupational Safety and Health Administration. Since electrical systems are essential in high-rise construction, emphasis was placed on engineering, administrative, and PPE controls rather than elimination.

- Engineering Controls

Engineering controls focused primarily on temporary power system redesign, as improper wiring accounted for 31% of observed hazards. Temporary electrical layouts were required to be designed and approved by qualified electrical engineers. Industrial-grade insulated cables, weatherproof distribution boards, elevated cable trays, and proper circuit labeling were mandated. Residual Current Circuit Breakers (30 mA sensitivity) were installed for all portable equipment circuits, with monthly functional testing to prevent fatal electrocution. Dedicated earthing systems were constructed, and quarterly earth resistance testing was introduced to maintain values below recommended limits. Load management controls included proper load calculation, installation of correctly rated MCBs/MCCBs, prohibition of multiple heavy machines on a single circuit, and thermal scanning inspections. Mechanical protection of cables using racks and ramps reduced insulation damage.

- Administrative Controls

A site-specific Electrical Safety Management Plan (ESMP) was implemented, covering inspection schedules, permit-to-work systems, and emergency procedures. Lockout-Tagout (LOTO) protocols were strictly enforced with isolation verification before maintenance. Weekly electrical inspections replaced monthly audits to improve monitoring frequency. Worker competency was enhanced through induction training, toolbox talks, and arc flash awareness programs. Only certified electricians were authorized to modify electrical installations.

- PPE and Environmental Controls

Mandatory arc-rated face shields, insulated gloves, dielectric shoes, and rubber mats were enforced. Panels were elevated and protected with waterproof enclosures to reduce wet-condition hazards. Post-implementation evaluation showed significant reduction in likelihood and severity ratings, shifting most hazards from Extreme to Medium or Low categories. These integrated controls ensure sustainable electrical safety in high-rise construction projects.

3.7. Result and Discussion

The study titled revealed significant findings regarding the nature, frequency, and severity of electrical hazards present at construction sites. Based on 48 structured inspections conducted across three high-rise projects, combined with worker interviews and PPE compliance observations, the results indicate that electrical risks remain a major safety concern in vertical construction environments. The inspection results showed that improper temporary wiring (31%) was the most frequently observed hazard. This highlights deficiencies in planning, supervision, and technical execution of temporary power installations. Since high-rise projects continuously expand vertically, electrical systems are frequently modified, increasing the possibility of loose joints, exposed conductors, and unsafe cable routing. Such conditions elevate the risk of electrocution and fire incidents. The second major issue identified was damaged cable insulation (21%), primarily caused by mechanical stress, material handling activities, and exposure to harsh environmental conditions. The absence of RCCB/ELCB protection in 17% of installations was particularly concerning, as these devices play a critical role in preventing fatal electric shocks. Their absence significantly increased risk scores to the Extreme category in the risk matrix assessment. Overloaded distribution boards (15%) and improper earthing (15%) were also identified as high-risk contributors. These deficiencies indicate inadequate load management and insufficient preventive maintenance practices. Additionally, the absence of proper danger signage (16%) reflects gaps in hazard communication and safety awareness. PPE compliance analysis revealed mixed results. While safety shoe compliance was relatively high at 81%, arc face shield usage was critically low at 42%, exposing workers to severe arc flash injuries. This demonstrates that although basic safety practices are somewhat adopted, advanced electrical safety precautions require stronger enforcement and training. Risk matrix evaluation categorized several hazards, including improper wiring, missing RCCB protection, damaged insulation, and wet working conditions, under the Extreme risk level, requiring immediate corrective action. Other hazards such as lack of Lockout-Tagout (LOTO), defective tools, and arc flash exposure were classified as High risk. The results clearly indicate that temporary electrical installations and poor procedural compliance are the dominant contributors to elevated electrical risks. The implementation of control measures including installation of RCCBs, improved cable management, strict LOTO enforcement, enhanced PPE compliance, and frequent electrical audits demonstrated a measurable reduction in risk levels. Post-control evaluation showed that many hazards shifted from Extreme to Medium or Low categories, confirming the effectiveness of engineering and administrative interventions. The findings emphasize that electrical accidents in high-rise construction are largely preventable through systematic planning, continuous monitoring, and strong management commitment. The discussion highlights the importance of integrating technical safeguards with behavioral safety strategies to establish a sustainable electrical safety culture.

Conclusion

The project titled highlights the critical nature of electrical hazards in vertical construction environments. The study confirms that electrical accidents remain a significant threat due to unsafe temporary installations, inadequate protective systems, insufficient supervision, and gaps in worker compliance with safety procedures. Through structured inspections, statistical analysis, and risk matrix evaluation, the research identified improper temporary wiring, damaged cable insulation, absence of RCCB/ELCB protection, overloaded distribution boards, and low arc flash PPE compliance as the most significant contributors to electrical risk. The risk assessment results demonstrated that several hazards fall under High and Extreme risk categories, requiring immediate corrective action. Temporary power systems were identified as the most vulnerable component, accounting for a major portion of observed deficiencies. Additionally, human factors such as lack of training, time pressure, and non-adherence to Lockout-Tagout (LOTO) procedures further increased the likelihood of incidents. Implementation of control measures based on the hierarchy of controls including engineering redesign, proper grounding, installation of leakage protection devices, enhanced inspection frequency, and strict PPE enforcement proved effective in reducing risk levels. Post-control evaluations indicated a shift of many hazards from Extreme to Medium or Low categories, demonstrating that systematic safety interventions significantly improve site safety performance. Electrical accidents in high-rise construction projects are largely preventable when supported by proper planning, strong management commitment, regular audits, and continuous worker training. Establishing a proactive electrical safety management system not only protects workers from injury and fatality but also enhances overall project efficiency and regulatory compliance.

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