

Breaking ground and breaching safety: a case study of construction health hazards

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ABSTRACT

Introduction: India's construction industry constitutes 16.4% of worldwide occupational dangers, although employing just 7.5% of the labor force, indicating significant safety shortcomings. Contributing elements encompass ineffective communication, absence of protective equipment, hazardous work practices, insufficient training, psychological strain, deficient safety culture, and restricted legal adherence. Notwithstanding the sector's multidisciplinary characteristics necessitating robust safety planning, insufficient protections persistently result in significant accidents and productivity declines.

Methods: This study investigates methods to improve safety performance utilizing Building Information Modeling (BIM) for proactive risk detection and real-time monitoring, alongside Blockchain for transparent and tamper-proof compliance administration.

Results: Blockchain guarantees secure compliance records, while BIM facilitates early hazard detection, improved risk visualization, and coordination. Together, these features improve accountability, lower accident rates, and increase overall construction safety.

Conclusion: By enabling proactive risk management and transparent compliance, lowering accidents, increasing productivity, and directing stakeholders toward successful digital adoption, the integration of BIM and Blockchain enhances construction safety.

Keywords: Building information modeling (BIM), blockchain, construction accidents

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Introduction

The construction sector in India is experiencing rapid growth due to extensive infrastructure renovation, gentrification, and government programs such as the Smart Cities Mission and the Pradhan Mantri Awas Yojana (PMAY). With the sector's expansion, the necessity for rigorous safety measures has grown more pressing. Construction sites generally entail heavy

machinery, intricate coordination, and a substantial, varied crew, factors that inherently increase the likelihood of accidents. Given that the construction sector is among India's greatest employers, enhancing safety protocols is both a legal obligation and a moral need.

Notwithstanding considerable modernization, the business persists in documenting a

substantial number of incidents annually, many of which lead to grave injuries or fatalities. The National Crime Records Bureau (NCRB) reports that construction is among India's most hazardous professions, with occurrences often attributed to insufficient training, lack of awareness, and negligence of safety regulations. Construction safety concerns are prevalent worldwide; yet Indian construction workers are among the most susceptible labor groups internationally. Due to the business's labor-intensive nature, safety must be addressed extensively at the national level.

Approximately 10 million individuals are directly working in construction, seeing four to five times more fatal events than their counterparts in industry. The Construction Industry Development Council (CIDC) reports that 165 per 1,000 workers have job-related injuries, with several individuals exposed to hazardous chemicals that may lead to silicosis, asbestosis, lead poisoning, and other occupational illnesses. The extensive unregulated construction workforce comprises more than 44 million people.¹ Despite constituting about 7.5% of the worldwide workforce, they comprise 16.4% of global occupational dangers. Research demonstrates that 62.8% of accidents occur on small construction sites, compared with 47.4% on larger projects,² highlighting disparities in safety standards and inadequate compliance with occupational health regulations. A significant portion of this data is underreported, obscuring the actual magnitude of the issue.³

The construction sector in India has a fatal accident frequency rate (FAFR) of 15.8 events per 1,000 workers yearly, about fifty times more than that of the United States. The International Labor Organization (ILO) indicates that the probability of both fatal and non-fatal accidents in India is 2.5 times higher than in North America or Europe.³ These figures indicate that India's safety standards are much inferior to international norms.

The continuous underreporting of occurrences significantly contributes to India's worrying accident rates. The ILO underscores the necessity of reporting and investigating accidents and occupational illnesses to identify risks and enact remedial actions. Nevertheless, in India, reporting remains unreliable.⁴ Numerous employees refrain from seeking medical attention or informing employers about injuries.^{4,5} Limited employee understanding, lack of support systems, employment instability, and fear of retribution inhibit reporting. Wider societal issues, such as feeble trade unions, language and caste disparities, socioeconomic inequities, governance deficiencies, and liberalized labor regulations, further obstruct transparent reporting.⁶

The construction labor is predominantly temporary, constantly relocating between sites. This engenders extremely volatile and intricate working conditions. This research investigates the many impediments to worker safety and health in the Indian construction sector and provides effective strategies to enhance safety performance.⁷

Table 1: Case Report on Occupational Safety in India's Construction Sector

Accident	Date	Place	Cause of the accident	Source
A tragic incident occurred at a construction site where nine workers lost their lives after a portion of the soil caved in.	Oct 12, 2024	Gujarat, Mehsana district	No safety Protocols	9 killed after soil caves in at construction site in Gujarat, PM condoles India News - Business Standard
A ceiling fall at a Peenya building site claimed the lives of two workmen.	August 10, 2024	Peenya, Bengaluru	Safety Concerns:	The Hindu reports that two workmen were killed when a

			Failure to follow safety procedures at the building site	ceiling collapsed at a Peenya building site.
(i) A worker died after falling from the twentieth story of a building that was still under construction.	September 3, 2023	Byculla (Mumbai)	Safety concerns: Lift and safety device certification and monitoring are handled by third-party companies rather than government organizations. It is noted that there is a shortage of technological know-how in monitoring safety measures.	Construction worker fatalities in Maharashtra have tripled in three years Mumbai News - Times of India
(ii) A worker was killed when a cargo lift crashed from the 17 th floor	June 15, 2023	Kurla (Mumbai)		
(iii) At a Bhiwandi site, a lift collapsed, killing two workers	November 22, 2022	Bhiwandi (Thane district)		
(iv) In Kandivali, a lift crashed, causing two workers to fall from the 24 th floor	August 27, 2020	Kandivali (Mumbai)		
This 28-year-old construction worker died when he stumbled and tumbled from a height of around 7.5 meters.	August 27, 2022	Pune	Failed to implement safety precautions such as setting up security netting and failing to give workers safety belts or helmets.	India's construction industry is perilous British Safety Council India
Gujarat saw 69 fatalities in 2014, 62 in 2015, 55 in 2016, 67 in 2017, and 137 fatal accidents in 2018.	May 12, 2019	Gujarat	Safety Concerns	India has 80% "unsafe" building sites and 20 times more fatalities than Britain.
According to 2016 research administered by IIT Delhi and the National Institute of Technology Surat, construction accounts for at least 11,614 of the approximately 48,000 deaths that occur in workplace accidents in India each year.	2016	India	Unsafe work practice	Indian construction is a precarious industry - British Safety Council India

Root Causes of Construction Mishaps: Identified from the real incidents

Construction accidents frequently result from a confluence of systemic, technical, and operational deficiencies. A primary factor is the use of inferior materials, often chosen to save costs. These materials compromise structural integrity and may fail to endure environmental stresses or load demands, resulting in fractures, erosion, or even collapse. This endangers public

safety and incurs costly repairs, legal ramifications, and a deterioration of confidence.

A crucial element is the noncompliance with safety requirements. Disregarding critical protocols, such as using safety harnesses, securing sturdy scaffolding, or providing sufficient protective equipment, significantly heightens the risk of falls, equipment malfunctions, and accidents. Disregarding technical norms during construction or

maintenance jeopardizes both worker safety and structural integrity.

Insufficient inspections and oversight also lead to incidents. When regulatory authorities or project overseers fail to conduct timely audits, hidden flaws go undetected. Such oversights might develop into significant structural issues that become apparent only after extensive harm has transpired.

Moreover, unrealistic timelines and financial constraints compel contractors to resort to shortcuts. Neglecting quality materials, minimizing competent personnel, or hastening processes may seem cost-effective but can lead to long-term safety risks and maintenance difficulties.

Unsafe Work Practices and Procedures- Causes:

The literature critique provides an overview of the numerous problems and difficulties related to workplace safety among Indian construction workers. Each of these concerns is covered in this section:

(i) Workplace Ergonomics

Injuries and illnesses in the construction sector can arise from inadequate postures, confined areas, elevated noise levels, vibrating equipment, severe temperatures,⁸ and disorganized work.⁹ These circumstances elevate physical stress and the probability of mistakes. Ergonomic redesign, enhancing work postures, task flow, and workplace configuration, can markedly increase comfort, diminish tiredness, and elevate safety.¹⁰

(ii) Enhancing On-Site Communication in Construction

The efficient dissemination of information continues to pose a significant issue on building sites. Information overload, delays, and inadequate communication with subordinate personnel foster hazardous workplaces.¹¹ Indian sites frequently rely significantly on manual oversight, and activities are seldom recorded systematically. The absence of record-keeping hinders the tracking of job progress, risk

assessment, and timely communication, hence undermining site coordination and safety.

(iii) Psychosocial Dynamics and Their Effects

Safety is affected by both physical circumstances and mental and cultural variables. Stress, weariness, anxiety, and burnout strongly influence employee behavior and performance,¹² a conclusion corroborated by international research.¹³ Extended hours, restricted social interaction, adverse weather conditions, and rigorous scheduling exacerbate stress levels among employees and supervisors.¹⁴ Indian construction projects frequently entail stringent timelines, constant vigilance, and task-related pressure, leading to psychological stress, interpersonal discord, and diminished general well-being.

(iv) Workplace Safety: Orientation and Behavioral Modification

Insufficient safety knowledge and careless attitudes towards dangers continue to prevail at several locations.¹⁵ Industrial safety ethics encompass collective convictions, competencies, and actions that mitigate risks. Establishing a robust safety climate characterized by clearly stated, practiced, and enforced regulations is crucial for enhancing compliance and mitigating accidents.

(v) Regulations Influencing Occupational Health and Safety Practices

Despite regulations such as the Occupational Safety, Health, and Working Conditions Code (2020) and prior legislation that provide safeguards, some workers in the unorganized sector remain unprotected.¹⁶ Enforcement deficiencies and implementation obstacles within the fragmented construction sector diminish the efficacy of these policies.^{17,18}

Solutions for Minimizing Construction Mishaps: Lessons from the Field

(i) Awareness Building and Capacity Development

Important elements influencing safety at Indian building sites include knowledge of potential

risks, the degree of risk posed by those risks, and the tools, equipment, and procedures available to mitigate them. Employees in the building industry sector frequently have low levels of education and are inexperienced, unskilled, and untrained. The likelihood and type of danger associated with the tasks these employees perform must be explained to them, and safety training programs must be implemented. When it comes to raising employees' awareness of the need to adhere to workplace safety regulations, management plays a crucial role.¹⁹

(ii) *BIM as a Catalyst for Safer Construction Environments*

One of the most neglected topics in the building sector has always been safety. Inadequate site safety leads to mishaps that cause both monetary and personal losses. Present-day security procedures are inadequate to oversee on-site safety, as detailed above. Automation is advancing rapidly and has several applications in construction safety. The Creation of a BIM-based automated safety checker model makes it clear that BIM is used for automated scaffolding,^{20,21} risk identification, and fall hazard identification.²² Furthermore, because of their many unique characteristics and capabilities,

BIM and Geographic Information System (GIS) integration are powerful platforms that are often utilized in the construction sector.²³ It facilitates the creation of safe construction zones,²⁴ and the digital representation of the actual environment by integrating BIM and GIS data.²³ Particularly when it comes to India, virtually little BIM has been used for safety. There isn't much research on BIM for framework systems,²⁵ BIM and GIS integration for site safety,²⁶ or BIM for site layout planning.²⁷ This section of the survey has been added to raise awareness of the potential applications of BIM for safety. It includes the safety benefits of BIM. The use of BIM might improve current procedures and highlight important issues with project time and expense overruns. Construction productivity has increased significantly in countries with BIM mandates, including the USA, the UK, France, Germany, and Singapore. If the anticipated long-term benefits are to be achieved, navigating India's lack of a BIM mandate in the near future will be a significant challenge. This section presents the opinions of construction experts on the BIM mandate, the steps required to comply with it, and BIM's future potential.

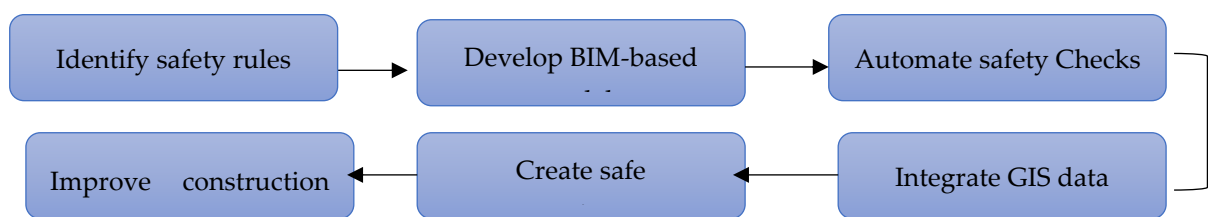


Figure 1: Integrating BIM for Enhanced Construction Safety

Table 2: How BIM Optimizes Safety Strategies in Construction

SI. No	Advantages of a Safety-First Approach
1.	Administration of a site's layout
2.	Modeling and picturing construction risks and precautions
3.	Prompt handling of potentially dangerous tools and supplies
4.	Swift and productive decision-making
5.	On-the-spot safety oversight and management
6.	Safety knowledge and instruction
7.	Appraisal of safety
8.	Risk-prone locations are identified for future use.
9.	Offering and notifying the employees of mitigation strategies
10.	Quantity take-off for required safety gear
11.	When required, issuing safety warnings to employees on the job site
12.	An automated method for verifying safety norms and requirements

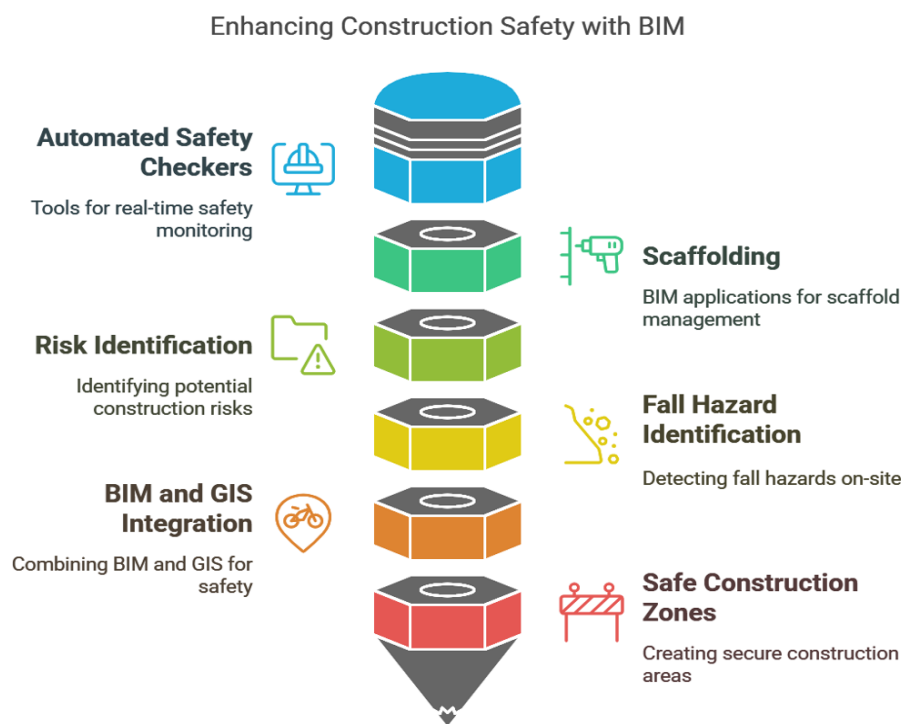


Figure 2: Safety enhancement with BIM

Automated safety inspections and AI-Driven risk evaluations facilitate danger identification, while IoT sensors and drones provide real-time monitoring of site conditions. Augmented Reality (AR) and Virtual Reality (VR) simulations offer immersive safety training for employees. BIM guarantees regulatory compliance through automated reporting and blockchain integration for secure safety documentation. Following construction, BIM facilitates facility management by forecasting maintenance requirements and enhancing emergency response strategies. Through the

integration of intelligent monitoring, predictive analytics, and automation, BIM markedly reduces construction hazards, thereby fostering a safer, more efficient, and more regulation-compliant work environment. Their use is essential for contemporary, safety-oriented building methodologies.

(iii) *Leveraging Blockchain for Enhanced Risk Management and Compliance*

Applying blockchain technology in risk management has exciting prospects.²⁸ For instance, look at the application of blockchain

technology to compliance checks in the building sector. They suggested using asset tracking and blockchain technology in tandem to address problems such as disputes, costly operations, and transparency issues. An enduring transaction record and semi-automated compliance tracking resulted from the structure of linked apps and an operational workflow they built. Similarly, while ensuring adherence to technical norms and standards, the SSI-based system facilitates the development of digitization processes.²⁹ Construction project risk management is also relevant to the POSH dissemination structure, which was previously covered in the context of record administration and preservation.³⁰ It specifically acts to strike a balance between privacy concerns and threats to workplace safety and health.

³¹ emphasized the potential of blockchain technology to improve on-site assembly inspection in modular construction, particularly during the COVID-19 pandemic, when remote and precise safety verification was crucial. Their prototype solution employed blockchain's

consensus process to enable project participants to authenticate module information, therefore assuring data correctness, transparency, and accountability in safety compliance. Likewise, illustrated blockchain's efficacy in enhancing equipment safety management, decision-making, accident monitoring, and supervision.³²

Blockchain is increasingly recognized as an essential instrument in building quality control, a crucial aspect of risk management.³² It proposed the "Product Organization Process (POP) Quality Chain," a blockchain-based system that incorporates smart contracts, consensus mechanisms, and POP-model clustering to oversee and verify construction quality data. ³³ demonstrated that blockchain establishes an immutable, decentralized record for the quality of items and processes. Recent findings demonstrate that experimental blockchain systems can improve the accuracy of information exchange during onsite modular assembly, thereby enhancing quality and risk management.

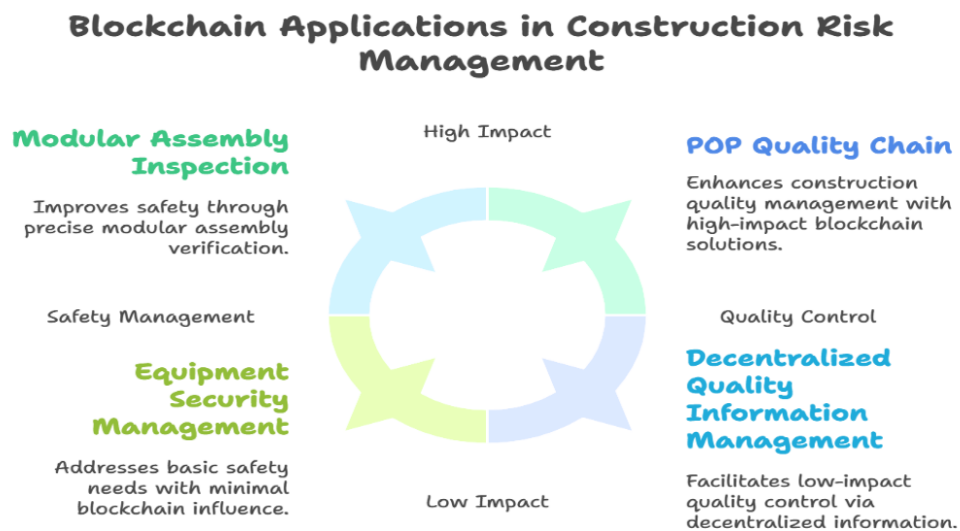


Figure 3: Blockchain applications in mitigating safety risks

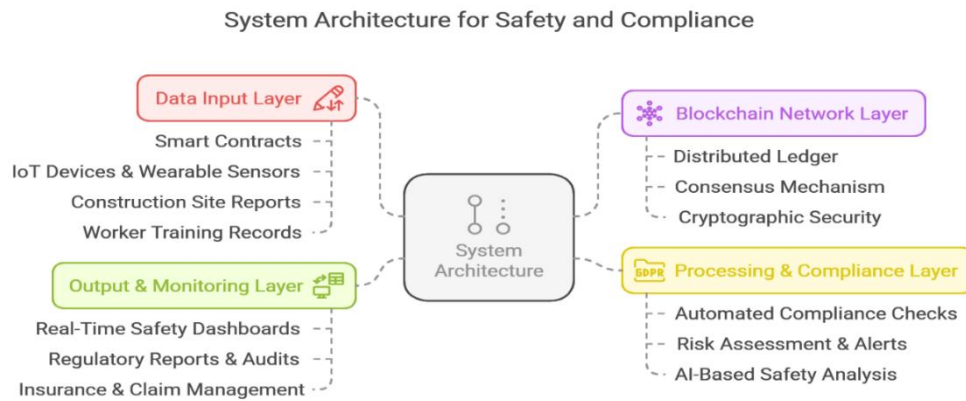


Figure 4: Blockchain architecture for safety compliance

Blockchain improves risk management and compliance in construction by providing secure, transparent, and automated procedures. IoT sensors, drones, and on-site inspections collect real-time data regarding safety compliance, material quality, and worker adherence to laws. Aggregated data is stored on a decentralized ledger, ensuring immutability and tamper-resistant records through blockchain integration. Smart contracts automate compliance checks, triggering notifications for infractions. Blockchain facilitates real-time safety monitoring, enabling regulatory authorities to remotely oversee building-site operations, thereby reducing the need for manual inspections. All stakeholders, contractors, regulatory bodies, and project managers have access to the encrypted safety record to ensure responsibility and mitigate fraud. AI-driven analytics on blockchain can forecast potential threats, facilitate proactive decision-making, and minimize mishaps. This application bolsters confidence, enforces compliance, and mitigates construction hazards, thereby enhancing overall project safety and efficiency.

Discussion

The Indian construction sector continues to face significant safety issues due to the use of substandard materials, inadequate worker training, unrealistic timelines, and widespread noncompliance with safety rules.^{34,35} Resolving these difficulties requires a comprehensive strategy that integrates technological

advancement, strengthened laws, and cultural transformation. This section outlines effective techniques to mitigate accidents and enhance safety performance at construction sites.

To ensure structural integrity, it is imperative that only superior materials be used. A compulsory third-party quality audit can authenticate products before utilization, bolstered by a nationwide register of accredited suppliers.³⁶ Integrating this register into governmental and corporate procurement processes can help prevent the introduction of substandard materials into projects. Companies that violate material requirements should incur severe consequences, such as fines or blacklisting, to discourage harmful behavior.³⁷

Safety compliance must be enhanced by technology-driven monitoring. IoT devices and wearable sensors can monitor employee mobility, identify hazardous circumstances, and deliver instantaneous notifications to supervisors.^{38,39} Financial sanctions and interim closures for non-compliance can enhance accountability. A consolidated repository of site-specific safety information would facilitate the identification of recurrent violators and bolster data-driven enforcement efforts.⁴⁰

Efficient oversight and examination are essential for accident prevention. Drones and AI-driven inspection tools may detect structural anomalies, risky practices, and hazardous areas in real time.⁴¹ Significant building initiatives must be subject to periodic evaluations performed by

independent safety organizations. These audits must assess equipment conditions, evaluate worker safety procedures, and ensure compliance with guidelines. Transparent disclosure of audit results can promote accountability and ongoing enhancement.⁴²

Impractical timetables frequently compel contractors to expedite tasks, jeopardizing safety⁴³. Advanced project management systems like Primavera and Microsoft Project facilitate the development of viable schedules that incorporate safety standards, cost, and time factors⁴⁴. Collaborative planning, including customers, contractors, engineers, and labor unions, ensures that safety is prioritized over expediency or financial constraints.

Mitigating the deficiency of a proficient workforce is vital. Collaborations with technical institutes can facilitate accredited training programs encompassing equipment operation, emergency response, and safety principles.⁴⁰ AR and VR training simulations help equip workers for real-world situations by familiarizing them with virtual threats and appropriate reaction strategies.⁴⁵

Suboptimal ergonomics is a primary contributor to occupational injuries. Ergonomically constructed tools, adaptable scaffolding, and lightweight equipment may alleviate physical strain and enhance efficiency.⁴⁶ Educating employees on safe posture, appropriate tool use, and manual handling techniques will further reduce musculoskeletal injuries.

Effective communication is essential for coordination and accident prevention. Wearable gadgets, such as smart helmets with integrated speakers and microphones, can improve communication, especially in emergencies⁴⁷. Multilingual training resources facilitate accommodating linguistic diversity among employees, whilst centralized communication tools enable supervisors to oversee workflows and proactively detect risks.

Psychosocial factors such as stress, weariness, and interpersonal conflict substantially impact

safety behavior.⁴⁸ Implementing on-site counseling, stress-relief initiatives, and rewards for safe behaviors can enhance morale and promote adherence. Identifying “safety champions” strengthens a culture of responsibility and vigilance.

Sustained safety enhancement necessitates behavioral modification. Consistent safety orientations and refresher courses facilitate the internalization of safe practices among workers. Designating qualified safety ambassadors on-site can facilitate peer learning and strengthen compliance with safety regulations. Ultimately, regulatory adjustments are essential. Implementing a standardized national safety code, periodically revised to incorporate technological and industrial advancements, can reduce uncertainty.⁴⁹ Consistent training for site managers guarantees adherence to changing rules.

Technological innovations such as Building Information Modeling (BIM), wearable sensors, and automated machinery may enhance safety by forecasting threats, monitoring worker health, and minimizing human error. Public-private collaborations may facilitate awareness campaigns, research, and training activities, while incentives such as tax advantages can motivate firms to prioritize safety. Implementing these measures can substantially reduce construction accidents in India, leading to safer work sites, increased productivity, and a stronger industry reputation.

Conclusion

The construction sector in India experiences a fatal accident frequency rate (FAFR) of 15.8 per 1,000 workers yearly, about 50 times more than that of the United States. The International Labor Organization (ILO) reports that the probability of both fatal and non-fatal accidents in India is 2.5 times higher than in North America or Europe, reflecting much worse safety standards.

A key contributor to these elevated accident rates is chronic underreporting. The ILO emphasizes

that accurate reporting and investigation of workplace accidents are crucial for risk identification; nevertheless, India's reporting is inconsistent. A multitude of employees refrain from reporting accidents owing to insufficient awareness, inadequate assistance, job uncertainty, and apprehension regarding company punishment. Wider social issues, such as weak trade unions, linguistic and caste barriers, economic inequalities, governance deficiencies, and lax labor laws, further hinder truthful reporting.

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