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# Integration of Lean Principles for Enhancing Safety Culture in the Indian Construction Industry

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***Abstract:** This study examines how Lean concepts can improve safety culture in the Indian construction industry, with a focus on high-rise building projects. While Lean concepts have been explored in construction safety worldwide, there has been little empirical research in India. This study evaluates the integration of various Lean tools and practices and their impact on enhanced safety results. Method: Data on the use of Lean techniques in Indian construction projects was collected through a detailed survey. The influence of Lean principles on safety was assessed using both theoretical analysis and empirical findings. The research focused on strategies that included collaborative planning, safety policy implementation, and worker participation in accident prevention. Findings: The study revealed that collaborative planning, robust safety policies, and worker participation are crucial for enhancing safety in high-rise construction. However, inadequacies in the learning environment were discovered, highlighting the need for continuous learning and improvement. Lean tools demonstrated their adaptability in addressing high-rise construction issues, thereby improving safety outcomes. Novelty: This study contributes to the limited research on Lean construction in India, particularly in the context of high-rise buildings. It offers unique insights into how Lean methods can overcome specific hurdles in the Indian construction sector, emphasising the need for further research into their long-term efficacy in enhancing safety culture.*

***Keywords:** Accidents; Construction; Health and Safety; Lean Principle; Lean Tools and Techniques*

## I. INTRODUCTION

India's construction industry, which on average contributes 8–10% of the country's GDP, plays a vital role in the country's growth. It employs around 41 million people, making it the second largest job provider behind the agricultural sector [1]. Being such a vast sector, accident statistics are not accurately and consistently reported [2]. 7.5% of the workforce worldwide is employed in Indian construction. However, this 7.5% of the workforce is exposed to 16.4% of all global occupational hazards [3]. Occupational accidents are not only a source of concern for employees, but they also have significant consequences for the organization's Overall economic and social health [4]. In India, around 48,000 people die because of occupational accidents, with the construction sector accounting for 28.20 per cent of all fatalities [5]. The construction industry is well recognized for being one of the riskiest, labour-intensive, fragmented, and dynamic sectors of the economy, despite its importance in terms of generating income [6]. One of the main reasons for accidents is an unsafe work environment. The Indian construction sector is still in the early stages of implementing safety regulations compared to other nations. Only a portion of India's building safety laws, such as the Building and Other Construction Workers Safety and Welfare Act of 1996, are implemented [2].

The study conducted by Vigneshkumar Chellappa [2], indicated that both individual and organizational factors contributed to the accidents. Personal factors include (1) lack of awareness and attitude, (2) lack of safety knowledge, (3) lack of danger information, and (4) breach of the code of practice, while poor safety planning and communication are unique organizational issues.

The typical H&S practice is divided into two phases: pre-construction and construction. During the pre-construction phase, safety is planned, executed, and monitored during the construction phase. Along with the standard characteristics (time, quality, and cost), H&S is recognized as one of the critical factors that can be readily compromised by inadequate H&S management. As a result, occupational health and safety improvements are inescapable, and they are a top focus for researchers [6].

Accidents on construction sites are becoming fatal, and the effects of damages are growing as projects get bigger and more high-rise [7]. They have a substantial influence on project performance, causing delays, cost overruns, poor quality, and, finally, low productivity. Poor safety performance is statistically the leading cause of accidents on construction sites, due to a variety of contributing factors. According to the Latham report "Constructing the Team" (1994), no construction project is risk-free. Managing the H&S aspects is thus essential for the success of any construction project [6]. A strong safety culture not only prevents accidents, but also promotes employee well-being, eliminates operational disruptions, protects organizational reputation, and contributes to long-term project success [8].

### A. Need for the Research

According to UN-Habitat, India's urban population is expected to exceed 600 million by 2030. As a result, India will need to open up many new growth avenues within its cities, prompting one to believe that high-rise buildings could become one solution to meet the demand for urban space [9]. High-rise building construction presents a significant challenge in terms

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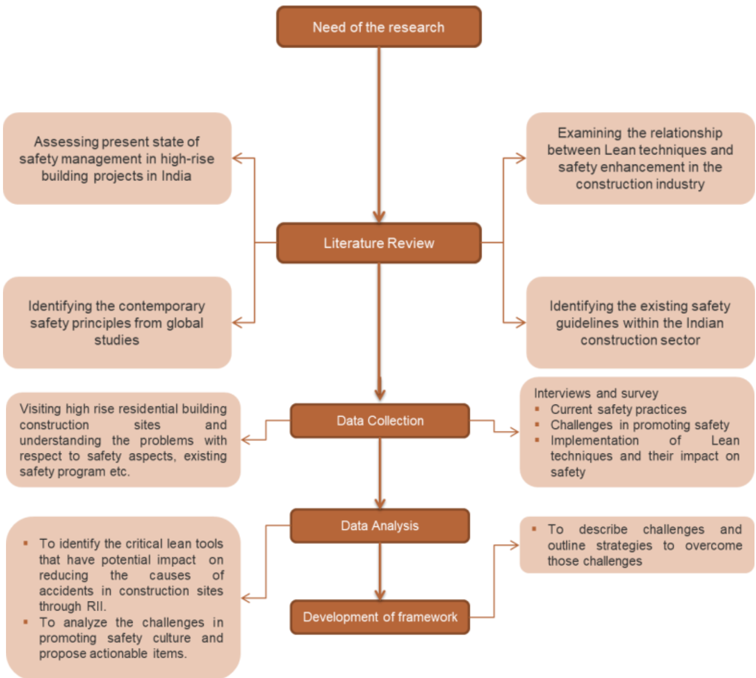
of safety performance, with high-altitude operations and the excavation of deep foundation trenches resulting in substantially higher accident rates and more severe injuries than those found in medium- and low-rise buildings [10]. Determining the implementation gaps that prevent the growth of a robust safety culture through assessment of current safety practices is thus necessary.

The study conducted by C. Vigneshkumar [11], recommends that safety practices and lean construction tools can be adopted to promote safety. According to a study conducted by S. Demirkesen [12], Lean thinking produces a cleaner workplace and a systematic workflow that needs less material in the work area, resulting in improved safety through standardization, systematization, and regularization of production. It also analyzed safety as a means [13] of managing uncertainty to allow proactive planning and reduce workflow variability from a Lean perspective. The study also suggested that Lean methods might be adopted to improve safety programs, encouraging safe behaviour, lowering injury rates, and enhancing communication efficiency at the project level.

The study conducted by John A. Gambatese [14], found a correlation between Lean principles and construction worker safety, claiming that Lean techniques helped increase worker safety. It also emphasises the need for further research, as follows: Although it is widely agreed that safety should be integrated into all managerial operations, it appears that additional study is needed in this area.

Over time, Lean construction principles have been adopted in various countries to enhance project efficiency, reduce waste, and improve safety outcomes. Lean methodologies, such as the Last Planner System (LPS), Visual Management, and Error-Proofing (Poka-Yoke), are recognised for streamlining operations and minimising workplace hazards. However, the use of these methods in India, particularly in high-rise constructions, is still restricted. Studies have established a positive association between Lean concepts and enhanced safety performance. However, empirical research within the Indian context is limited. This study aims to fill the research gap by examining the application of Lean concepts in the Indian construction industry, with a focus on enhancing safety in high-rise residential projects. This initiative aims to demonstrate the effectiveness of Lean concepts in transforming the safety culture and practices of the Indian construction industry by identifying and addressing specific causes of accidents, such as falls from heights and scaffolding collapses, through the application of Lean technologies. Ultimately, this study aims to contribute to a more sustainable and safer building environment, with the long-term goal of achieving zero accidents on high-rise sites.

## II. METHODOLOGY




### A. Primary Data - Questionnaire Survey

The questionnaire survey, conducted with professional stakeholders in India's construction industry, addresses the high level of uncertainty surrounding lean factors. It has six sections: A gathers respondent experience, roles, project details, and financial aspects. B explores common safety hazards, safety practices, and challenges in promoting a culture of safety. C and D focus on integrating safety into project scheduling. E asks respondents to rate the impact of lean techniques on on-site safety. F assesses specific lean techniques related to accident causes in high-rise residential construction.

### B. Reliability of Questionnaire

*i.Cronbach's Alpha Method*

Cronbach's alpha was used to assess the reliability of the survey scale by investigating the internal consistency of the responses regarding the LC techniques. The normal range of Cronbach's coefficient

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alpha value is between 0.0 and +1, and higher values reflect a higher
degree of internal consistency, with 0.70 generally considered as the minimum accepted value.

The following table presents the results of the Cronbach's alpha test. This range is considered high when it is above 0.70. Thus, the result ensures the reliability of the questionnaire and suggests that the LC techniques are internally consistent.

| Lean Techniques | Cronbach's α |
|---|---|
| All techniques | 0.989 |
| Lean technique to improve construction site safety | 0.968 |
| A lean technique for a fall from height accident | 0.942 |
| Lean technique for Scaffolding collapse | 0.942 |
| A lean technique for being struck by a falling object | 0.947 |
| Lean Technique for Material Handling Accidents | 0.947 |
| Lean technique for Crane accidents | 0.930 |
| Lean technique for Plant & Machinery accidents | 0.925 |

The data gathered through the questionnaire were then subjected to descriptive analysis using the mean score, standard deviation and relative importance index (RII).

## C. Relative Importance Index Technique

To analyse the order of significance of the factors, the relative value of each factor as received by the respondents is expressed by the Relative Importance Index (RII) (Chan 2012). This method is one of the most used and has a highly accurate value when rating factors using a questionnaire.

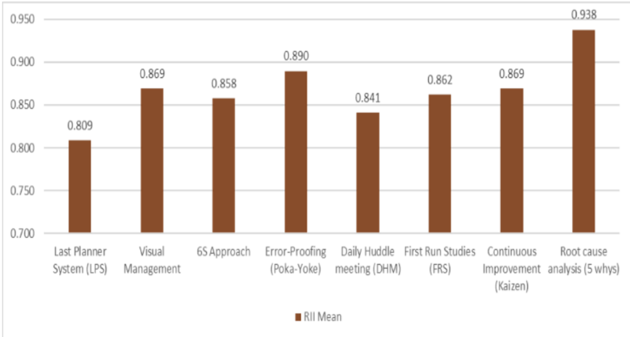
Relative Importance Index (RII) –

$$RII = \frac{\sum W}{A * N}$$

# III. RESULTS AND DISCUSSIONS

## A. Techniques to Improve Safety

The findings are derived from data collected through a survey of professional stakeholders in India, primarily safety managers, highlighting key strategies perceived as most effective in improving safety on construction sites. "Root cause analysis (5 whys)" emerges as the most prioritized, with a high RII mean of 0.938, securing the top rank, and indicating its substantial importance in identifying the underlying causes of accidents or errors. "Error-Proofing (Poka-Yoke)" follows closely behind, reflecting its significance in ensuring safety measures, with an RII mean of 0.890, emphasizing its essential role in preventing errors and accidents before they occur. "Visual management" and "Continuous Improvement (Kaizen) also demonstrate notable importance, securing ranks within the top five with an RII mean of 0.869.




**[Fig.1: Lean Tools and Their Mean of RII]**

**Table 1: Lean Tools and Techniques Perceived as Most Effective in Improving Safety on Construction Sites**

| Methods | Lean Tools | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Last Planner System (LPS) | Visual Management | 6S Approach | Error-Proofing (Poka-Yoke) | Daily Huddle meeting (DHM) | First Run Studies (FRS) | Continuous Improvement (Kaizen) | Root Cause Analysis (5 Whys) |
| Lean Techniques | 8 | 3 | 5 | 3 | 2 | 2 | 2 | 1 |
| RII Mean | 0.809 | 0.869 | 0.858 | 0.89 | 0.841 | 0.862 | 0.869 | 0.938 |
| Rank | 8 | 3 | 6 | 2 | 7 | 5 | 3 | 1 |

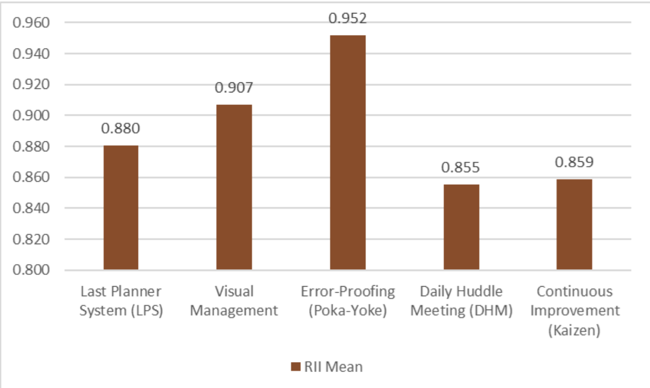
*Techniques to Improve Safety for Different Causes of Accidents in High-Rise Residential Buildings Falling From Height*

Table 2 indicates that among the Lean techniques aimed at enhancing safety in high-rise residential construction, focusing specifically on fall accidents, Error-Proofing (Poka-Yoke) emerges as the top-ranking tool, with the highest RII mean of 0.952, signifying strong agreement on its efficacy in enhancing fall safety measures. Visual Management follows closely behind, reflecting its significant role with the RII mean of 0.907, indicating its importance in visually highlighting fall hazard zones and safety protocols. The Last Planner System (LPS), while ranking third, still maintains an RII mean of 0.880, reflecting its significant role in planning and coordinating safety protocols to prevent falls.

**Table 2: Lean Tools and Techniques to Improve Safety for Fall from Height Accident**

| ID | Lean Tool | Lean Technique | No. Of. Respondents selecting | | | | | Total Weightage (W) | Total responses (N) | A*N | RII | RII (%) | Mean | Standard Deviation | RII Mean | Rank |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Strongly disagree (1) | Disagree (2) | Neutral (3) | Agree (4) | Strongly agree (5) | | | | | | | | | |
| FT1 | | Providing employees with safety equipment | 1 | 1 | 2 | 0 | 25 | 134 | 29 | 145 | 0.924 | 92.41 | 4.62 | 1.015 | 0.880 | 3 |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | (e.g., harnesses, helmets). | | | | | | | | | | | | | | |
| FT2 | Last Planner System (LPS) | Develop a plan for supervision to ensure proper adherence to safety protocols. | 1 | 1 | 1 | 6 | 20 | 130 | 29 | 145 | 0.897 | 89.66 | 4.48 | 0.986 | | |
| FT3 | | Developing a schedule based on workers' abilities to minimize fatigue and potential errors. | 0 | 1 | 4 | 7 | 17 | 127 | 29 | 145 | 0.876 | 87.59 | 4.38 | 0.862 | | |
| FT4 | | Correlating work methods with workers' skills and abilities to ensure tasks are performed safely. | 0 | 2 | 3 | 7 | 17 | 126 | 29 | 145 | 0.869 | 86.90 | 4.34 | 0.936 | | |
| FT5 | | Involving all employees in safety planning increases awareness of fall hazards. | 0 | 1 | 1 | 16 | 11 | 124 | 29 | 145 | 0.855 | 85.52 | 4.28 | 0.702 | | |
| FT6 | | Conducting pre-task hazard analysis to identify fall risks and implement necessary precautions. | 0 | 1 | 2 | 13 | 13 | 125 | 29 | 145 | 0.862 | 86.21 | 4.31 | 0.761 | | |
| FT7 | Visual Management | Using visual demarcations and boards on-site to highlight fall hazard zones. | 1 | 0 | 1 | 10 | 17 | 129 | 29 | 145 | 0.890 | 88.97 | 4.45 | 0.870 | 0.907 | 2 |
| FT8 | | Using safety signs and labels on-site to warn workers of fall hazards. | 0 | 2 | 2 | 1 | 24 | 134 | 29 | 145 | 0.924 | 92.41 | 4.62 | 0.903 | | |
| FT9 | Error-Proofing (Poka-Yoke) | Using safeguards and Personal Protective Equipment (PPE) such as guardrails, safety nets, and fall arrest systems. | 0 | 1 | 1 | 2 | 25 | 138 | 29 | 145 | 0.952 | 95.17 | 4.76 | 0.689 | 0.952 | 1 |
| FT10 | Daily Huddle Meeting (DHM) | Conducting daily meetings to increase communication and awareness of fall hazards. | 0 | 1 | 7 | 4 | 17 | 124 | 29 | 145 | 0.855 | 85.52 | 4.28 | 0.960 | 0.855 | 5 |
| FT11 | Continuous Improvement (Kaizen) | Involving all employees in safety planning increases awareness of fall hazards. | 0 | 1 | 1 | 16 | 11 | 124 | 29 | 145 | 0.855 | 85.52 | 4.28 | 0.702 | 0.869 | 4 |
| FT12 | | Conducting pre-task hazard analysis to identify fall risks and implement necessary precautions. | 0 | 1 | 2 | 13 | 13 | 125 | 29 | 145 | 0.862 | 86.21 | 4.31 | 0.761 | | |




**[Fig.2: Lean Tools and Their Means of RII for Fall from Height Accident]**

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**Table 3: Lean Tools and Techniques That Would Significantly Improve the Safety of the Construction Site Concerning Fall-From-Height Accidents in High-Rise Residential Building**

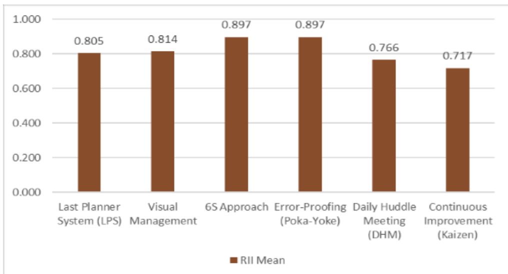
| Methods | Lean Tools | | | | |
|---|---|---|---|---|---|
| | Last Planner System (LPS) | Visual Management | Error-Proofing (Poka-Yoke) | Daily Huddle meeting (DHM) | Continuous Improvement (Kaizen) |
| Lean Techniques | 6 | 2 | 1 | 1 | 2 |
| RII Mean | 0.88 | 0.907 | 0.952 | 0.855 | 0.859 |
| Rank | 3 | 2 | 1 | 5 | 4 |

## B. Scaffolding Collapse

**Table 4: Lean Tools and Techniques to Improve Safety for Scaffolding Collapse**

| ID | Lean Tool | Lean Technique | No. Of. Respondents Selecting | | | | | Total Weightage (W) | Total responses (N) | A*N | RII | RII (%) | Mean | Standard Deviation | RII Mean | Rank |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Strongly disagree (1) | Disagree (2) | Neutral (3) | Agree (4) | Strongly agree (5) | | | | | | | | | |
| ST1 | Last Planner System (LPS) | Develop a plan for supervising the installation and maintenance of scaffolding to ensure proper execution. | 0 | 1 | 3 | 11 | 14 | 125 | 29 | 145 | 0.862 | 86.21 | 4.31 | 0.806 | 0.805 | 4 |
| ST2 | | Developing a schedule based on workers' abilities to prevent overloading and ensure safe usage. | 0 | 1 | 7 | 7 | 14 | 121 | 29 | 145 | 0.834 | 83.45 | 4.17 | 0.928 | | |
| ST3 | | Conducting pre-task hazard analysis specifically addressing scaffolding stability and integrity. | 0 | 6 | 7 | 9 | 7 | 104 | 29 | 145 | 0.717 | 71.72 | 3.59 | 1.086 | | |
| ST4 | Visual Management | Using visual demarcations and boards on-site to indicate safe load limits and proper assembly. | 0 | 1 | 9 | 6 | 13 | 118 | 29 | 145 | 0.814 | 81.38 | 4.07 | 0.961 | 0.814 | 3 |
| ST5 | 6S Approach | Organizing materials and equipment to prevent clutter and obstruction of scaffolding. | 0 | 1 | 4 | 4 | 20 | 130 | 29 | 145 | 0.897 | 89.66 | 4.48 | 0.871 | 0.897 | 1 |
| ST6 | Error-Proofing (Poka-Yoke) | Conducting visual inspections of scaffolding regularly. | 0 | 1 | 4 | 6 | 18 | 128 | 29 | 145 | 0.883 | 88.28 | 4.41 | 0.867 | 0.897 | 1 |
| ST7 | | Using safeguards such as tie-offs, bracing, and proper anchoring. | 0 | 1 | 4 | 2 | 22 | 132 | 29 | 145 | 0.910 | 91.03 | 4.55 | 0.870 | | |
| ST8 | Daily Huddle Meeting (DHM) | Conducting daily meetings to discuss scaffolding safety and address any concerns. | 0 | 2 | 9 | 10 | 8 | 111 | 29 | 145 | 0.766 | 76.55 | 3.83 | 0.928 | 0.766 | 5 |
| ST9 | Continuous Improvement (Kaizen) | Conducting pre-task hazard analysis specifically addressing scaffolding stability and integrity. | 0 | 6 | 7 | 9 | 7 | 104 | 29 | 145 | 0.717 | 71.72 | 3.59 | 1.086 | 0.717 | 6 |

Table 4 highlights that among the Lean techniques designed to mitigate accidents related to scaffolding collapse in high-rise residential construction, the 6S Approach stands out as the top-ranking tool, with the highest RII mean of 0.897, emphasising the importance of organising materials and equipment to prevent hazards effectively. Additionally, Error-Proofing (Poka-Yoke) is equally effective with the highest RII mean of 0.897. Following closely behind is Visual management, with an RII mean of 0.814, which ensures safe assembly through the use of visual aids and demarcations.




**[Fig.3: Lean Tools and Their Means of RII for Scaffolding Collapse]**

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**Table 5: Lean Tools and Techniques that Would Significantly Improve the Safety of the Construction Site Concerning Scaffolding Collapse in High-Rise Residential Building**

| Methods | Lean Tools | | | | | |
|---|---|---|---|---|---|---|
| | Last Planner System (LPS) | Visual Management | 6S Approach | Error-Proofing (Poka-Yoke) | Daily Huddle meeting (DHM) | Continuous Improvement (Kaizen) |
| Lean Techniques | 3 | 1 | 1 | 2 | 1 | 1 |
| RII Mean | 0.805 | 0.814 | 0.897 | 0.897 | 0.766 | 0.717 |
| Rank | 4 | 3 | 1 | 1 | 5 | 6 |

## C. Struck by a Falling Object

**Table 6: Lean Tools and Techniques to Improve Safety for Struck by a Falling Object**

| ID | Lean Tool | Lean Technique | No. Of. Respondents selecting | | | | | Total Weightage (W) | Total responses (N) | A*N | RII | RII (%) | Mean | Standard Deviation | RII Mean | Rank |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Strongly disagree (1) | Disagree (2) | Neutral (3) | Agree (4) | Strongly agree (5) | | | | | | | | | |
| OT1 | Error-Proofing (Poka-Yoke) | Providing employees with safety equipment, such as hard hats and safety helmets, to protect against head injuries. | 0 | 2 | 5 | 2 | 20 | 127 | 29 | 145 | 0.876 | 87.59 | 4.80 | 1.015 | 0.876 | 2 |
| OT2 | Last Planner System (LPS) | Developing a plan for supervision to ensure proper storage and handling of materials to prevent objects from falling. | 0 | 2 | 4 | 5 | 18 | 126 | 29 | 145 | 0.869 | 86.90 | 4.34 | 0.974 | 0.848 | 3 |
| OT3 | | Conducting pre-task hazard analysis to identify potential hazards related to falling objects and implementing necessary precautions. | 0 | 1 | 6 | 10 | 12 | 120 | 29 | 145 | 0.828 | 82.76 | 4.14 | 0.875 | | |
| OT4 | Visual Management | Using visual demarcations and boards on-site to designate safe areas for material storage and handling. | 0 | 1 | 3 | 17 | 8 | 119 | 29 | 145 | 0.821 | 82.07 | 4.10 | 0.724 | 0.841 | 4 |
| OT5 | | Using safety signs and labels on-site to warn workers of potential falling objects. | 0 | 1 | 5 | 7 | 16 | 125 | 29 | 145 | 0.862 | 86.21 | 4.31 | 0.891 | | |
| OT6 | 6S Approach | Organizing materials and plant equipment to prevent them from falling or being knocked over. | 0 | 1 | 5 | 4 | 19 | 128 | 29 | 145 | 0.883 | 88.28 | 4.41 | 0.907 | 0.883 | 1 |
| OT7 | | Separating necessary tools from unnecessary materials helps reduce clutter and minimise the risk of objects falling. | 0 | 1 | 6 | 2 | 20 | 128 | 29 | 145 | 0.883 | 88.28 | 4.41 | 0.946 | | |
| OT8 | Daily Huddle Meeting (DHM) | Conducting daily meetings to increase communication and awareness of falling object hazards. | 0 | 1 | 10 | 9 | 9 | 113 | 29 | 145 | 0.779 | 77.93 | 3.90 | 0.900 | 0.779 | 6 |
| OT9 | Continuous Improvement (Kaizen) | Conducting pre-task hazard analysis to identify potential hazards related to falling objects and implementing necessary precautions. | 0 | 1 | 6 | 10 | 12 | 120 | 29 | 145 | 0.828 | 82.76 | 4.14 | 0.875 | 0.828 | 5 |

Table 6 indicates that among the Lean techniques aimed at addressing accidents related to being struck by falling objects in high-rise residential construction, the 6S approach emerges as the top-ranking tool, with the highest RII mean of 0.883, highlighting its significance in organizing materials to prevent objects from falling. Error-proofing (Poka-Yoke) closely follows, with an RII mean of 0.876, emphasising its crucial role. Despite ranking third, the Last Planner System has a mean RII of 0.848, highlighting its significant role in planning and


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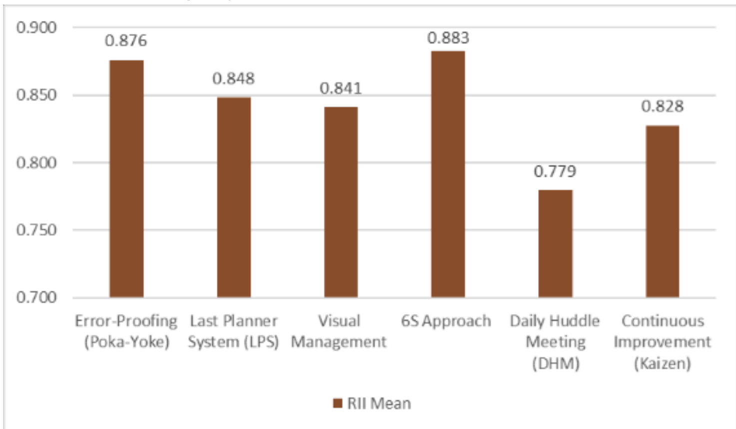
coordinating safety measures related to falling objects.




**[Fig.4: Lean Tools and Their Means of RII for Struck by Falling Objects]**

**Table 7: Lean Tools and Techniques that Would Significantly Improve the Safety of the Construction Site Concerning Struck by Falling Objects in High-Rise Residential Building**

| Methods | Lean Tools | | | | | |
|---|---|---|---|---|---|---|
| | Error-Proofing (Poka-Yoke) | Last Planner System (LPS) | Visual Management | 6S Approach | Daily Huddle meeting (DHM) | Continuous Improvement (Kaizen) |
| Lean Techniques | 1 | 2 | 2 | 2 | 1 | 1 |
| RII Mean | 0.876 | 0.848 | 0.841 | 0.883 | 0.779 | 0.828 |
| Rank | 2 | 3 | 4 | 1 | 6 | 5 |

Data was collected for material handling accidents, crane accidents, and plant and machinery accidents in high-rise residential construction. For each accident type, Lean tools and techniques, such as Error-Proofing (Poka-Yoke), the 6S Approach, and Visual Management, were analysed for their effectiveness in improving safety, ranked by their RII means. The findings underscore the crucial role of targeted strategies in mitigating risks and promoting safer construction environments.

## D. Material Handling Accidents

Error-proofing (Poka-Yoke) is the most impactful technique with the highest RII mean of 0.938, emphasizing its importance in promoting safety. The 6S Approach (RII mean 0.924) and the Last Planner System (LPS) (RII mean 0.874) rank second and third, respectively, indicating their roles in enhancing material handling safety.

## E. Crane Accidents

The 6S Approach and Error-Proofing (Poka-Yoke) share the highest RII mean of 0.924, highlighting their critical roles in crane safety. Visual Management (RII mean of 0.914) ranks next, emphasising the importance of visual aids, such as exclusion zones, to prevent accidents.

## F. Plant & Machinery Accidents

Error-proofing (Poka-Yoke) leads with an RII mean of 0.934, underscoring its importance in mitigating risks. Visual Management follows with an RII mean of 0.924, demonstrating its effectiveness in hazard communication, while Daily Huddle Meetings (RII mean 0.910) rank third, showing their value in fostering regular safety discussions.

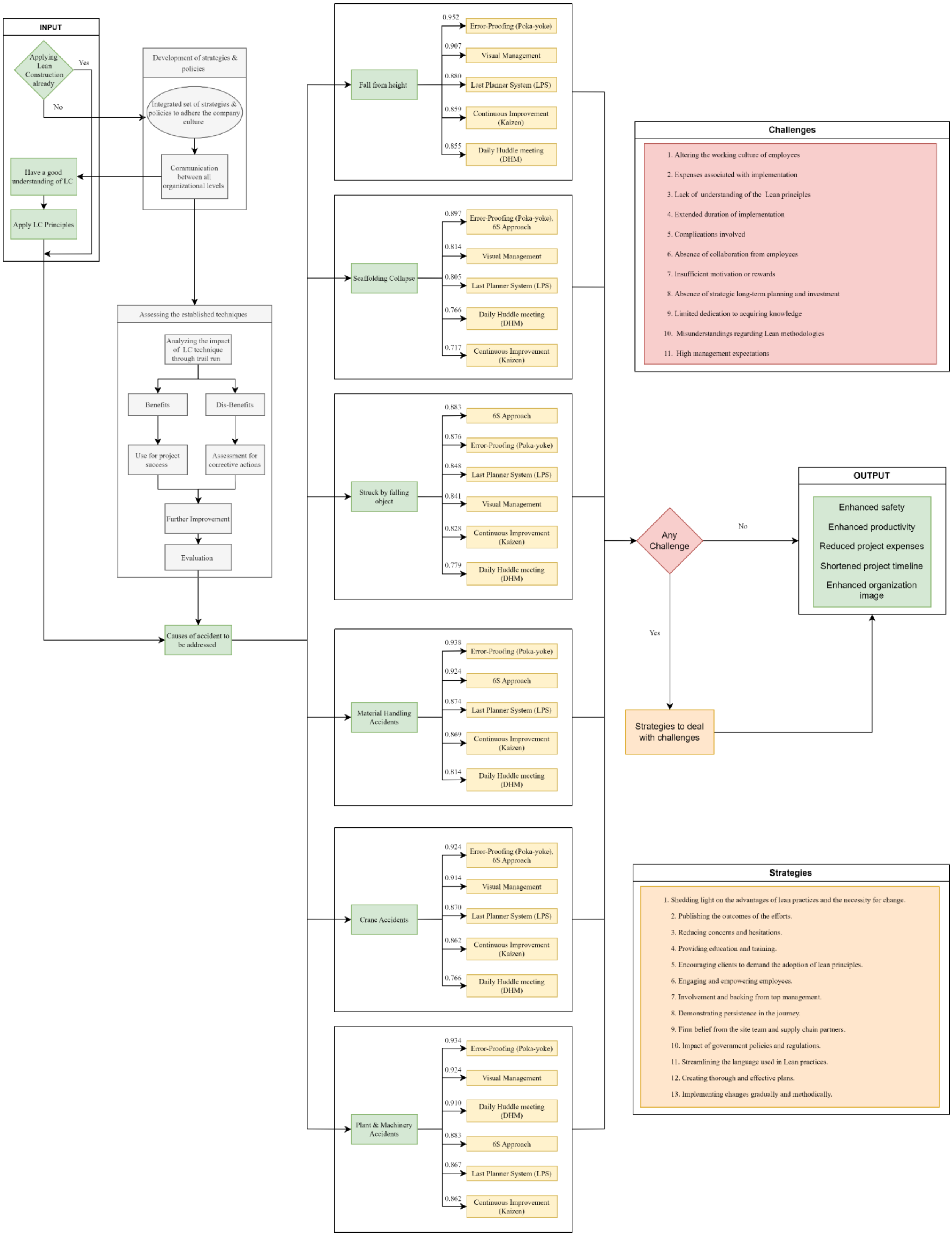
The study examines the integration of Lean principles with safety guidelines to enhance safety in the Indian construction sector. It identifies common hazards in high-rise residential projects, such as falls, material handling accidents, and scaffolding collapses. Emphasising robust safety measures and training, the study identifies critical accident-prone construction stages, such as civil work. It highlights the effectiveness of Lean techniques, such as error-proofing and regular inspections, in preventing accidents. The study also addresses challenges such as deadline pressures and inconsistent enforcement of regulations, suggesting strategies like regular training evaluations and fostering a shared safety responsibility.

Based on expert interviews and analysis of survey results, the study of the Building and Other Construction Workers (BOCW) Act, 1996, is conducted, recognising its pivotal role as a mandatory guideline followed across all construction sites in India. By focusing on the BOCW Act, its widespread applicability and significance within the construction industry are acknowledged. Given its widespread adoption and enforcement, understanding the provisions and requirements outlined in the BOCW Act enables us to evaluate the efficacy of current safety guidelines and practices critically. This comprehensive examination enables us to pinpoint areas where improvements or enhancements may be needed to ensure the optimal protection and well-being of construction workers.

**Table 8: Finding Gaps in Existing Safety Guidelines Within the Indian Construction Sector and Proposing Actionable Items by Identifying and Integrating Lean Principles**

| Challenges in Promoting Safety Culture and Enforcing Safety Protocols Among Workers | Existing BOCW Guideline | BOCW Guideline with Lean Technique Incorporated | Enhanced Safety After Incorporation |
|---|---|---|---|
| Negligence of workers despite Training | Mandates the provision of safety training and welfare measures. | Implement regular evaluation of training effectiveness using a continuous improvement technique. Utilize digital platforms for easy access to training materials and assessments. | Improved retention and application of safety knowledge among workers. |
| Resource/Budget Allocation due to financial limitations | Mandates the provision of welfare facilities but lacks a specific allocation for safety. | Introduce Lean budgeting techniques, such as Value Stream Mapping, and provide incentives for companies to allocate budgets specifically for safety measures. Encourage collaboration for resource sharing. | Increased allocation of resources for safety, resulting in improved safety infrastructure and practices. |
| Workers are prioritizing deadlines over safety. | No direct provision addressing prioritization of deadlines over safety. | Incorporate Lean scheduling techniques, such as the Last Planner System, which mandates safety breaks during tight deadlines and prioritises safety over deadlines. | Reduction in accidents due to enforced safety breaks and penalties for negligence. |
| Workers prioritize safety only when management emphasizes its importance | Emphasises the employer's responsibility for a safe working environment. | Introduce Lean management practices, which require regular safety audits by management and the formation of safety committees for shared responsibility. Implement rewards for exemplary safety leadership using Kaizen events. | Enhanced safety culture with active involvement of management and workers in safety promotion. |
| Safety measures not integrated into the Project Management process | Does not explicitly require the integration of safety measures into project management. | Mandate safety risk assessments in project planning using Lean principles. Include safety metrics in project management frameworks. Provide Lean training for project managers. | Improved safety planning and coordination throughout the project lifecycle. |
| Collective Responsibility for Safety | Emphasizes employer responsibility but may lack promotion of collective responsibility. | Encourage collaboration through Lean initiatives and anonymous reporting systems. Foster open communication and mutual support. | Enhanced safety culture with shared responsibility among all project personnel. |
| Inconsistent enforcement of the regulation | Lays down regulations for safety standards, but enforcement may be inconsistent. | Strengthen enforcement through Lean methods, such as regular inspections and transparent reporting systems. Promote self-regulation and peer monitoring using 5S methodology. | Increased compliance with safety regulations and a reduction in violations. |
| Lack of awareness and education | Mandates safety induction programs but lacks effectiveness for workers with limited education. | Utilise lean training methods, such as visual aids and Gemba walks, that cater to diverse educational backgrounds. | Improved understanding and application of safety measures among all workers. |
| Perception of Safety – Viewing it as an impediment to productivity rather than a necessity for their well-being | Emphasizes the importance of a safe working environment but may not address negative perceptions of safety. | Conduct surveys and implement Lean rewards systems to promote safe behaviour. | Cultivation of a positive safety culture and mindset among workers. |
| Pressure to Meet Deadlines | Does not directly address pressure to meet deadlines at the expense of safety. | Introduce regulations and Lean techniques to optimise workflow while maintaining safety. Offer incentives for completing projects ahead of schedule with exemplary safety records, utilising Lean project management. | Reduction in accidents due to reduced pressure and efficient time management. |

The Lean-Safety Integration framework is based on insights gathered from a thorough study and comprehensive data collection, highlighting the effectiveness of various Lean techniques in mitigating safety risks. By integrating Lean principles, the framework offers a structured approach to enhancing safety standards in construction projects.




**[Fig.5: Lean – Safety Integration – Framework]**

To improve safety in the Indian construction industry, particularly for high-rise residential buildings, this framework involves a comprehensive assessment and application of LC principles to develop strategies and guidelines that enhance safety and productivity while reducing project expenses and timelines. The process begins with identifying common causes of accidents, such as falls from heights, scaffolding collapses, and crane accidents, and using LC techniques like error-proofing (Poka-yoke), the 6S approach, visual management, the Lean Planner System (LPS), daily huddle meetings (DHM), and continuous improvement (Kaizen) to address these issues. Challenges include the need for cultural adaptation, extensive training, and overcoming misconceptions about lean methodologies. Strategies to address these challenges involve highlighting the benefits of lean practices, sharing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success stories, simplifying training, engaging employees, promoting teamwork, initiating pilot projects, and incorporating lean principles into project schedules. The gradual and methodical implementation ensures thorough integration, ultimately enhancing safety, productivity, and organizational reputation.

The study builds on previous research by extending Lean principles to high-rise construction projects, a more accident-prone environment. While Chellappa [2] focused on general Lean tools for safety, this study applies methods like Error-Proofing and the Last Planner System to address specific hazards such as falls. Similarly, it aligns with Demirkesen's [12] findings on Lean's impact on workplace safety but emphasizes its effectiveness in the Indian context, particularly in high-rise projects. The study introduces a tailored framework, highlighting the use of Visual Management and Daily Huddle Meetings, which were not as extensively explored in previous research.

This study contributes to the field by focusing on the underexplored application of Lean principles for safety in high-rise residential construction in India. It integrates Lean tools, such as Value Stream Mapping and Kaizen, into Indian safety regulations, addressing gaps in enforcement and enhancing the safety culture. The

The study also stands out for its specific focus on preventing accidents, such as falls and scaffolding collapses, offering practical, data-validated solutions that go beyond the general safety strategies found in previous research.

## IV. CONCLUSION

This study has delved into the critical domain of enhancing safety culture within the Indian construction sector, with a specific focus on high-rise residential buildings. Through the integration of Lean principles, the research has introduced a comprehensive framework designed to reduce accidents and cultivate a safety-oriented environment among labourers. By identifying primary accident causes and addressing them through targeted strategies, the framework provides a methodical approach to enhancing safety standards at construction sites.

The study's findings outline effective Lean techniques for enhancing safety on construction sites, highlighting several key strategies. Root Cause Analysis (5 Whys) is identified as the most crucial strategy, with an RII mean of 0.938, underscoring its importance in determining the underlying causes of accidents. Error-proofing (Poka-Yoke) is consistently highlighted across various safety aspects, demonstrating its significant impact with high RII means, such as 0.952 for fall prevention, 0.897 for scaffolding collapse, and 0.938 for material handling safety. Visual Management also plays a pivotal role, with RII means of 0.907 for fall safety and 0.924 for plant and machinery safety, emphasizing the importance of clear visual demarcations and hazard communication. The Last Planner System (LPS) is effective in planning safety protocols, with notable RII means of 0.880 for fall safety and 0.848 for preventing accidents from falling objects. Additionally, the 6S Approach is crucial for plant and machinery safety (RII mean of 0.897) and material handling operations (RII mean of 0.924). Daily Huddle Meetings (DHM) are highlighted for their role in fostering ongoing safety communication for plant and machinery safety, with an RII mean of 0.910.

However, it is crucial to recognise the limitations of this study, particularly the absence of real-world applications of the proposed framework. Subsequent research endeavours should emphasize practical trials and validation to evaluate the actual effectiveness of the framework in ongoing construction projects.

Additionally, it is essential to acknowledge the dynamic nature of the construction field and the evolving landscape of safety issues. Continuous improvement and adaptation of safety procedures and methodologies are vital to ensure relevance and efficiency in addressing emerging hazards.

In conclusion, the primary objective of this study is to contribute to the broader goal of promoting a safer and more sustainable construction environment in India. By advocating for the integration of Lean principles and promoting a safety-oriented culture, we can work towards the common goal of zero accidents and guarantee the welfare of labourers.

Future research should prioritize field testing and validation of the proposed framework in real-world construction projects across diverse settings within the Indian context. Collaborating with industry partners to implement the framework in pilot projects can provide valuable insights into its practical applicability and effectiveness. Furthermore, exploring partnerships with regulatory bodies and professional associations can facilitate broader adoption and standardization of the framework across the construction industry.

## DECLARATION STATEMENT


After aggregating input from all authors, I must verify the accuracy of the following information as the article's author.

- **Conflicts of Interest/Competing Interests:** Based on my understanding, this article does not have any conflicts of interest.
- **Funding Support:** This article has not been sponsored or funded by any organization or agency. The independence of this research is a crucial factor in affirming its impartiality, as it was conducted without any external influence.
- **Ethical Approval and Consent to Participate:** The data provided in this article is exempt from the requirement for ethical approval or participant consent.
- **Data Access Statement and Material Availability:** The adequate resources of this article are publicly accessible.
- **Author's Contributions:** The authorship of this article is contributed equally to all participating individuals.


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