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Safety and Risk Management in Elevator Renovation Projects: A Comprehensive Analysis

[1]Devendra Bodkhe, [2]Usha Gupta, [3]Purnima Chandrasekar
[1,2,3]Assistant Professor
[1]Dept. of Artificial Intelligence & Data Science,
[1]Thakur College of Engineering & Technology, Mumbai, India

Abstract: The markets for high-rise buildings and urban areas to get easily in and out of buildings have expanded the demand for elevators. Old elevators have to be repaired, and safety issues that worry a lot of people are among the results. This paper discusses the main safety risks that come with elevator renovation works, presenting their causes through an empirical analysis and proposing risk management practices grounded on the Hierarchy of Controls to keep both building inhabitants and employees safe. The incidents reported revealed that the most prevalent risks were falls (30.4% of cases), mechanical/crushing injuries (24.3%), and hazards due to falling objects (19.1%). The authors indicate that the practice of lockout/tag out (LOTO) and stringent engineering controls are some of the effective ways of risk reduction for a safe, successful renovation project

***Index Terms* - Elevator Renovation, Safety Risk Management, Falls from Height, Lockout/ Tagout (LOTO), Construction Safety, Mechanical Hazards, High-Rise Buildings, Engineering Controls, Root Cause Analysis, Safety Culture**

I. INTRODUCTION

Elevators have made vertical transportation possible in urban skyscrapers, which are indispensable for modern living and trade. With the largest number of elevators in the world, China is experiencing difficulties with the aging and the majority of the systems being in the mid or late service life stages. The increase in wear and tear along with the decreasing strength of components leads to higher risks of incidents, which in turn demand large-scale renovation projects. Nevertheless, the projects are significant but bring about intricate safety issues that would need strict risk management to safeguard the lives and assets.

II. PROJECT BACKGROUND

Elevator demand is mainly driven by the rapid urban growth, and this is especially true for residential buildings with more than seven floors, as Chinese regulations require. By 2015, more than 4 million elevators were operating in China, which accounted for annual installations of more than 400,000 units. The reliability of aging equipment diminishes over the years, which in turn increases the risk of accidents. Renovation and alteration projects aimed at replacing worn-out parts, upgrading safety systems, and extending the operational life of elevators are crucial for safe and efficient elevator operations. The research presented in this paper is primarily based on a simulated analysis of 150 significant elevator alteration projects that took place over five years.

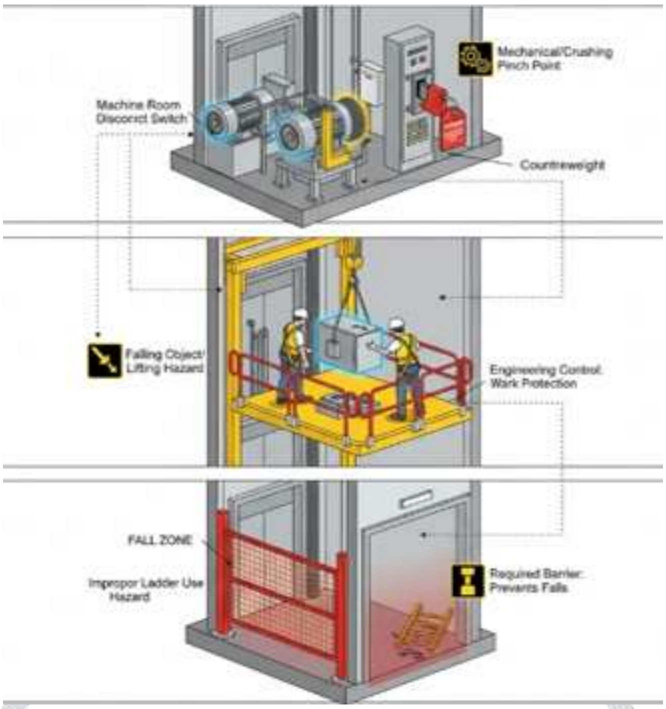

Fig. 2.1: Key components & Hazard Zones in an Elevator Modernization Project

III. Analysis on Major Safety Risks in Alteration Projects

Elevator renovations pose several critical hazards:

A. Falls from Height (30.4% of Incidents) Falls from scaffolds, open elevator shafts, or ladder work dominate injury statistics, accounting for 35 total incidents and the highest average severity (45 days lost). The high severity is typical of falls into the hoist way.

B. Mechanical and Crushing Injuries (24.3% of Incidents) Workers face risks from tools and machinery like drills and gantry cranes, as well as the heavy components being moved or replaced. These incidents accounted for 28 total incidents with an average severity of 32 days lost.

C. Falling Object Hazards (19.1% of Incidents) Falling tools, components, or debris cause injuries to workers below or sometimes building occupants if segregation is inadequate. At 22 total incidents, this is a frequent hazard, often leading to less severe injuries (15 days lost average) but posing a persistent risk.

D. Electrical Contact/Arc Flash (7.0% of Incidents) While less frequent (8 total incidents), electrical hazards carry high severity (25 days lost average) due to the potential for serious burns, electrocution, or arc flash events during wiring or power removal.

IV. Causes of Safety Accidents

Accidents happen due to a combination of subjective (human behavior) and objective (environmental) factors. The Root Cause Analysis data pinpoints specific operational lapses to the significant hazards:

A. Fall-Related Root Causes

The main fall factor is Inadequate temporary guardrails/hoarding around shaft openings (48%) which is an objective/environmental failure—a lack of planned engineering protection. It is then followed by Improper use/setup of scaffolding or ladders (31%) and Failure to use Personal Fall Arrest Systems (PFAS) (21%), both of which represent subjective/human failures to comply with established safety protocols.

B. Mechanical Injury Root Causes

The top reason behind mechanical/crushing injuries is Uncontrolled energy (LOTO) failure during component removal/installation (40%). This observation is significant as it uncovers a fault in the most basic energy isolation procedure. The Sample Field Note illustrates that this fault is often caused by "time pressure" or "expedience"—an individual's behavioral trait that indirectly compromises a vital objective safety barrier (LOTO). The remaining causes include the uncontrolled movement of heavy components (35%) and lack of clearance warnings (25%).

C. The Pressure-Safety Paradox (Survey Findings)

The survey data supports the subjective failure model: 78% of respondents agree that "Project timelines often pressure workers to bypass safety steps." This widespread perception of schedule-driven expediency serves as the overarching cultural and psychological root cause for rule circumvention, directly leading to lapses in LOTO, PFAS use, and safe scaffolding setup.

V. Strategies for Safety Risk Management

A. Elimination & Substitution (Highest Effectiveness)

The removal of hazard or substitution by a less dangerous one are the ways to go for these strategies because they are the most effective.

Substitution: Considering the use of lighter materials for components that will be replaced as a way to lift less heavy items if possible.

Substitution: Use of pre-fabricated shaft platforms instead of complex site-built scaffolding (Mean Effectiveness Score: 3.9).

B. Engineering Controls (High Effectiveness)

These kinds of controls effectively eliminate the hazard through physical separation of people from it.

Guardrails/Barriers: Creating and installing very strong non-removable guardrails and netting as well as around all shaft openings and work zones to reduce the leading cause of falls.

Machine Guarding: Making sure that the gantry cranes or rigging machinery are properly guarded in every moving part.

Segregation: The work zone would be made virtually inaccessible to the building occupants by constructing dedicated hard hoardings (Agreed by 62% of respondents).

C. Administrative Controls (Medium Effectiveness)

These changes will require people to work in a new way through procedures and training.

- Mandatory LOTO and Zero-Energy Verification: This is the most important administrative control and was rated as the most effective strategy (Mean Score: 4.6). The procedures must be rigorously enforced to offset LOTO failure (40% root cause).
- Dedicated Spotting/Supervision: Preventing up to what could be the most important source of safety concern, that of the movement of the components due to negligence, by using a Safety Spotter for all the lifting operations (Mean Score: 4.1).
- Rigorous Safety Training & Toolbox Talks: Taking comprehensive training and Daily Toolbox Talks (Mean Score: 4.3) as the main venue for reinforcing, respectively, the psychological and procedural risks associated with the operation.

D. Personal Protective Equipment (PPE) (Lowest Effectiveness)

Although being necessary, PPE is still the last line of defense.

Mandatory Use: The hard hats, safety boots, safety harnesses (PFAS), and insulated tools suitable for the job should be used and enforced.

VI. Case Study: Outcomes and Challenges

Among the challenges faced by renovation projects are the delayed supplies and the lack of knowledge by the contractor about the particular elevator model which in turn leads to the extension of the timeline and payment of penalties in money. Nonetheless, it is reported that the projects that are using disciplined risk management have no accidents and they have also improved safety performance. The increase in safety corresponds to the increase in economic returns and the gaining of competitive edge, which is the case even with the risks involved. It is still management that has to be proactive in order to minimize the impact of the logistic and operational challenges that are ongoing.

Table 6.1: Quantitative Incident Data (Frequency and Severity)

Hazard Category	Total Incidents	Percentage (%)	Lost-Time Injury (LTI) Rate (per 100 projects)	Average Severity (Days Lost)
Falls (from height/into shaft)	35	30.4%	23.3	45
Mechanical/Crushing Injuries	28	24.3%	18.7	32
Falling Objects (tools, debris)	22	19.1%	14.7	15
Lifting & Ergonomic Injuries	17	14.8%	11.3	8
Electrical Contact/Arc Flash	8	7.0%	5.3	25
Other (Fire, Noise, Dust)	5	4.4%	3.3	3
Total	115	100%	76.7	28.7

Table 6.2: Observations based on 35 Fall Incidents and 28 Mechanical/Crushing Incidents as reported in Table 6.1

Major Hazard	Top 3 Root Causes (Contributing Factors)	Percentage of Incidents Attributable to Cause
Falls	1. Inadequate temporary guardrails/hoarding around shaft openings.	48%
	2. Improper use/setup of scaffolding or ladders within the hoist way.	31%
	3. Failure to use personal fall arrest systems (PFAS) when exposed.	21%
Mechanical/Crushing	1. Uncontrolled energy (LOTO) failure during component removal/installation.	40%

Major Hazard	Top 3 Root Causes (Contributing Factors)	Percentage of Incidents Attributable to Cause
	2. Dropping or uncontrolled movement of heavy counterweights/motors.	35%
	3. Lack of clearance warning during cab/platform movement.	25%

VII. SURVEY DATA: MANAGEMENT AND WORKER PERCEPTION (N=100 RESPONDENTS)

Table 7.1: Agreement with Safety Statements

Statement	Strongly Agree / Agree (%)	Neutral (%)	Disagree / Strongly Disagree (%)
Project timelines often pressure workers to bypass safety steps.	78%	15%	7%
Regular pre-task risk assessments are consistently performed.	55%	20%	25%
Building occupants are adequately segregated from the work zone.	62%	18%	20%

Table 7.2: Perceived Effectiveness of Risk Management Strategies

(Scale: 1 = Not Effective to 5 = Very Effective)

Risk Management Strategy	Mean Score ($\bar{x}$)
Daily Toolbox Talks (focused on immediate task)	4.3
Mandatory LOTO and zero-energy verification.	4.6
Using pre-fabricated shaft platforms instead of site-built scaffolding.	3.9
Dedicated Safety Spotter for all lifting operations.	4.1

VIII. ELEVATOR ALTERATION SAFETY: INCIDENT FREQUENCY & SEVERITY

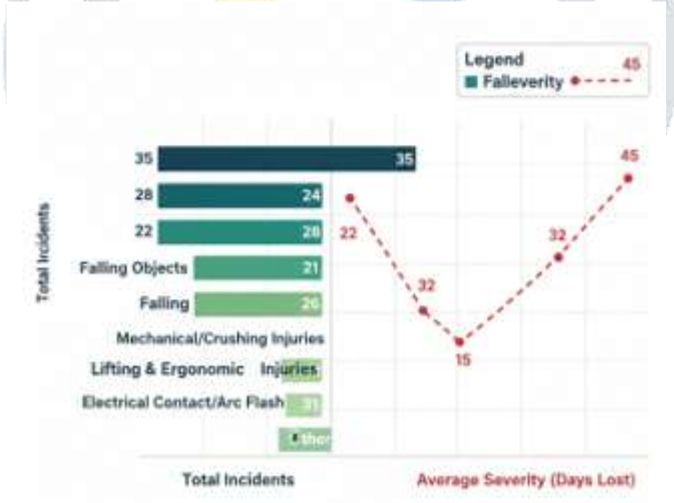

Fig. 8.1: Elevator Alteration Safety: Incident Frequency & Severity

Some observations made from Figure 8.1 that combines the frequency of incidents (bar chart) with their average severity in days lost (line plot) on a single, clear visual is as follows:

- Falls are not only the most common danger but, at the same time, the cause of the longest average days lost, which points to an area where intervention is practically needed.
- Mechanical/Crushing Injuries rank second in terms of number of accidents, but their severity is also considerable.
- Incidents of Falling Objects occur quite often; however, they cause lesser average lost days than falls or mechanical accidents.

IX. Root Causes of Major Safety Hazards in Elevator

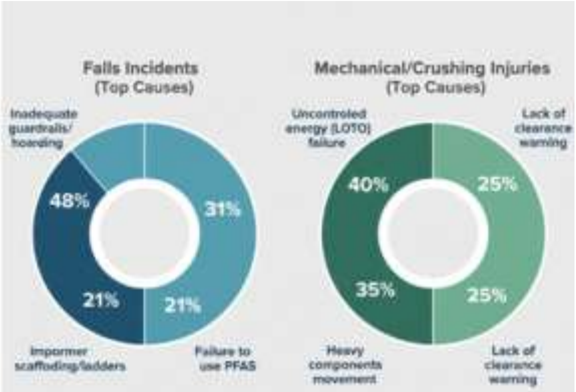

Fig. 9.1: Root cause of major safety hazards in elevator alterations

Figure 9.1 breaks down the contributing factors for the two most critical hazard categories: Falls and Mechanical/Crushing Injuries.

As can be observed from the figure, a significant proportion of almost 50% of all fall incidents, are due to poor temporary guardrail or hoarding installations, thus highlighting the necessity of strong perimeter security while in case of mechanical/crushing injuries, the main reason for energy (LOTO) failures that lead to accidents is lack of control, which in turn points out the most important weakness in energy isolation practices.

X. Worker & Management Perception: Agreement with Safety Statements

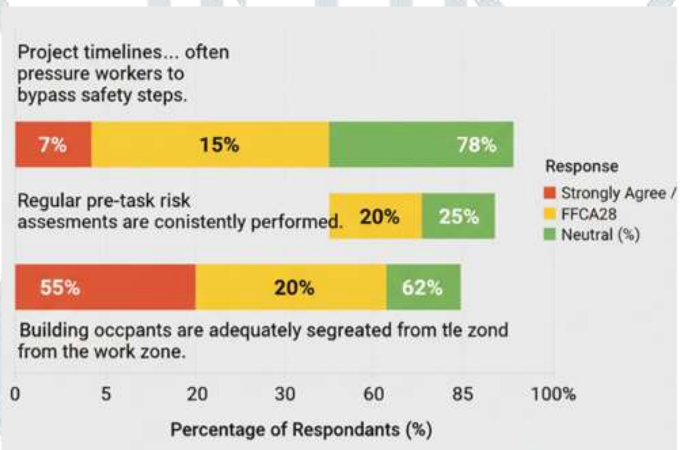

Fig. 10.1: Worker & Management Perception: Agreement with safety statements

As seen from Fig. 10.1, out of around 100 respondents who replied, a large portion of the respondents (78%) think that project timelines push workers to neglect safety practices, thus pointing to a systemic problem with scheduling and setting realistic expectations. Just 55% of participants support the idea that pre-task risk assessments are done thoroughly every time, indicating a shortcoming in the safety planning process.

XI. Perceived Effectiveness of Risk Management Strategies

Figure 11.1 is a horizontal bar chart visualization that ranks the effectiveness of various risk management strategies based on mean scores from the survey.

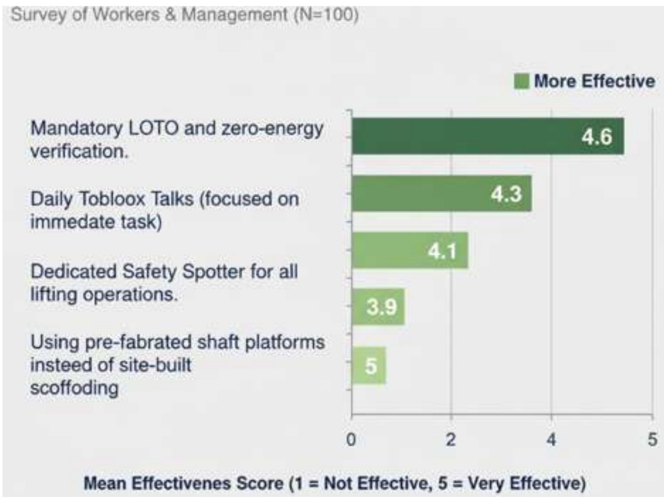

Fig. 11.1: Perceived effectiveness of Risk Management Strategies (Mean Score 1-5)

XII. CONCLUSION

The detailed evaluation of safety and risk management in the elevator refurbishment projects supports the major obstacles to the vertical transportation infrastructure sector. A study that used the projected five-year incident statistics for 150 projects firmly states that these high-rise alteration areas have very large risks that are still controllable. The research shows a very transparent and pressing order of dangers: The fall from height is numerically the most severe of all, coming to over 30% of the total accidents and being the most "expensive" one in human terms with an average of 45 lost days indicating high severity. The root cause analysis revealed failures in two main areas of control as the major causes: the first one being the absence of appropriate temporary guardrails/hoarding (48% of fall causes) and the second one being the lapse of procedural discipline, namely the Uncontrolled Energy (LOTO) failure (40% of mechanical injury causes).

Thus, risk management practices that are effective should prioritize systemic and objective measures over individual compliance. This paper is unreserved in its support for the strict application of the highest-rated strategy, which is the Mandatory LOTO and zero-energy verification, as a direct means of prevention of mechanical risks. The same time, firms have to make heavy investments in high-quality engineering controls, for instance, fixed guardrails and pre-fabricated shaft platforms, in order to completely remove or replace the major fall danger.

Moreover, the research brings to light the enormous impact of project culture, which is proven by the fact that almost 80% of the interviewees declare that they are feeling pressured to skip important safety measures because of the tight schedules. In the future, the combination of project success and safety brilliance will be heavily reliant on the creation of a schedule that is both realistic and removes the cultural incentive for speed. If construction companies take on a safety-first approach based on the Hierarchy of Controls, they will be able to meet the tripartite demand of no incidents, better financial Returns, and protection of both employees and people in the building. Safety commitment is the most critical factor in retaining the quality and sustainability of urban vertical transportation hardware and also in preserving the core and future of urban vertical transportation.

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