

## Safety Risk in High Rise Construction Projects

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### ABSTRACT

*The planning of high-rise structures right from the project inception stages involves various challenges and risks. With great heights comes a greater risk and risks manifolds when safety is at stake. Safety being one of the apex importance's in high rise construction projects. Lack of safety measures and health precautions results not only in casualties, injuries and diseases due to accidents, incidents and potential health hazards but has impacts on families, communities, commerce and economy. The safety risks have adverse effect on the productivity of work, quality standards and causes time overrun thereby creasing the project cost. Deficiency in safety and health measures include loss of client's property, loss of goodwill of the personnel or companies involved in the project causing their blacklisting. For executing the projects within scheduled time and cost constraints, it is of utmost importance that hazards, near misses, incidents, accidents and fatalities are reported and root cause of same may be identified to mitigate in upcoming activities of the project. Operating machineries, plants, equipment considering all safety parameters, reducing lost time injuries and increasing safe man hours are of prime importance to safety officers, project managers and client's representatives in high rise construction projects. All efforts have been made to identify, analyse critical safety risks, find gaps and suggest mitigation strategies for safety risk in high rise construction projects.*

**Keywords.** *Safety, risks, high rise construction, work at height and vertical logistics*

### INTRODUCTION

High rise buildings especially in semi urban and urban areas are the showcase of human invention, technological growth, financial capabilities and project management advancement. They are symbols of centurion growth and occupants' aspirations. There is a preposition of building mixed usage types in high rise buildings, making them a one stop solution for all the routine activities (Sidana, AVSM, VSM (Retd.) & Paul, 2022).[19,25] With advanced planning, emerging materials, sophisticated plants, machineries, advanced analysis and precise execution have led these high-rise

structures take their desired form and shape (Paul, et al., 2017).[20] The statistic from Indian government says that the area of the country is about 33 lakhs square km and the population is about 140 crores, thus making land resource to the country a precious one, especially in urban areas.[16]

Risk is an unforeseen circumstance or incident that could have a favorable or unfavorable impact on the project's goals if it materializes. The planning of high-rise structures, right from various stages especially during construction have many challenges and hence can be exaggerated

as risks. [11] The majority of present high rise building projects proposed in NCR region are attracting a height of more than 30 meters and reaching up to 90 meters or even more, covering up huge built-up area, bearing heavy estimated costs and taking a substantial estimated completion time. On an average 1 out of 3 high rise construction projects in NCR are delayed, stressed and then stalled as per CREDAI report due to one reason or another having a root cause of a risk factor behind it. Accidents are not happening, they are caused, that means someone is causing it either by doing things which are not correct or by not doing things which are correct.[2] The critical accidents involving workforce, material handling and mechanical operations happening on sites are directly related to safety of life and resources, which itself envisages a thorough need for safety risk management. 11614 people die in construction accidents in India each year as per a study by NIT Surat in year 2016 (Viswanathan & Jha, 2020). 38 People die in construction accidents in India every day as per article in the Indian Express in 2019. 39.2% of the total accidents happen due to fall from height as per a study by IIT Delhi.[23,31]

The research questions which this paper tries to address are as mentioned further. What are the critical risks related to related to manpower safety, material safety, equipment safety and machine safety in high rise construction projects? What are the gaps between HSE practices mentioned in on site safety procedures adopted for high rise construction projects? What are the potential strategies for risk reduction,

monitoring control in high rise construction projects?[12]

The aim of this research is to identify, analyse critical safety risks, find gaps and suggest mitigation strategies for safety risk in high rise construction projects. The first **objective** of the research is to identify the critical safety risks related to work at height and vertical logistics for high rise buildings (above G+15). The second objective of this research is to find out the gaps in safety management plan for the listed safety risks and related issues faced at site. The third objective is to suggest the reasons for the gaps and safety risk mitigation strategies for high rise construction projects.[13]

## LITERATURE REVIEW

The risk assessment matrix has been prepared considering all the identified risks in literature studies. Prepared a risk matrix listing all the possible risks and assign them markings based upon certain predefined criteria in qualitative analysis with the identified 29 number risks from 12 number of literature studies, prepared a questionnaire and got in touch with experts working on high rise projects in any capacity, get their feedback and based on the results made the matrix and achieved conclusive results. The technique used for risk assessment is relative important index (RII) has been used to evaluate how important the criteria are. Each response category is given a weight between one and four and the average weight for each element is then calculated to determine the RII as below:

**Table 1: Legend for Risk Assessment Matrix. (4×4 Risk Matrix), Source Author.**

<b>Legend for Risk Assessment Matrix. (4×4 risk matrix)</b>				
Likelihood/ Consequences.	<b>Very Likely</b>	<b>Likely</b>	<b>Unlikely</b>	<b>Highly Unlikely</b>
Example Factor 01	Very High	Very High	High	Medium
Example Factor 02	Very High	High	Medium	Medium
Example Factor 03	High	Medium	Medium	Low
Example Factor 04	Medium	Medium	Low	Low

Very Likely = 4, Likely = 3, Unlikely = 2, Highly Unlikely = 1 and  
Very High = 4, High = 3, Medium = 2, Low = 1.

**Table 2: Safety Risk Assessment Matrix, Source Author.**

<b>Safety Risk Ranking Matrix.</b>						
Sn	Risks Description	Probability	Likelihood or Impact	Risk	Risk	Literature Sources for Risks
				Amount	RII	
1	Construction or execution related risks.	Likely (3)	High (3)	$3 \times 3 = 9$	3	(Chauhan, et al., 2022)[3]
2	Structure risks.	Likely (3)	Very High (3)	$3 \times 3 = 9$	3	(Chavan & Deshmukh, 2016)[4]
3	Safety and risks of falling objects.	Very Likely (4)	Very High (4)	$4 \times 4 = 16$	1	(Chouksey, et al., 2020) [5,32]
4	Legal compliances risks.	Likely (3)	Medium (2)	$3 \times 2 = 6$	5	(Kumar Mishra, et al., 2021)[1]
5	Legal cases by third parties/ legal allegations/ court stays.	Likely (3)	High (3)	$3 \times 3 = 9$	3	(Devika, et al., 2020)[6]
6	Real estate market risks.	Likely (3)	High (3)	$3 \times 3 = 9$	3	(Kumar & Singhal, n.d.)[9,10]
7	Slow speed due to PCB guidelines.	Very Likely (4)	Medium (2)	$4 \times 2 = 8$	4	(Nayal, et al., 2020)[17]
8	Fire risks during construction.	Likely (3)	Very High (4)	$3 \times 4 = 12$	2	(Prakash Giri, et al., n.d.)[22]
9	Earthquake risks during construction.	Likely (3)	Very High (4)	$3 \times 4 = 12$	2	(Sanni-Anibire, et al., 2020)[24]
10	Safety and equipment's risks.	Very Likely (4)	Very High (4)	$4 \times 4 = 16$	1	(Wei, et al., n.d.) (Zhang, et al., 2018)[32]
11	Design and planning related risks.	Likely (3)	Very High (4)	$3 \times 4 = 12$	2	(Sanni-Anibire, et al., 2020)[24]
12	Safety hazards and risks	Very Likely (4)	Very High (4)	$4 \times 4 = 16$	1	(Wei, et al., n.d.)[32]
13	Soil settlement below the building.	Un Likely (2)	Very High (4)	$2 \times 4 = 8$	4	(Supraja, n.d.) (Tabish & Jha, n.d.)[27,29]
14	Vertical transportation risks	Very Likely (4)	Very High (4)	$4 \times 4 = 16$	1	(Nayal, et al., 2020) (Tabish & Jha, n.d.)[17,29]
15	Wrong selection of construction technology or construction method risks.	Likely (3)	Very High (4)	$3 \times 4 = 12$	2	(Tayyab, et al., 2023)[30]
16	Modern formwork systems related risks	Likely (3)	Very High (4)	$3 \times 4 = 12$	2	(Swaroop Devaiah & Keshav, 2022)[28]
17	Concrete planning and placer booms related risks.	Likely (3)	Very High (4)	$3 \times 4 = 12$	2	(Yadav, et al., 2021)[33,34]
18	Construction sequence	Likely (3)	Very High	$3 \times 4$	2	(Judson & Paul,

	related risks.		(4)	=12		2022)[7]
19	Site logistics related risks.	Likely (3)	Very High (4)	3 × 4 =12	2	(Zhang, et al., 2018)[37]
20	Hoist operation related risks.	Likely (3)	Very High (4)	3 × 4 =12	2	(Zhang & Pan, 2021)[38]
21	Tower cranes operation related risks.	Very Likely (4)	Very High (4)	4 × 4 =16	1	(Nayal, et al., 2020) (Subramanyan, et al., 2012)[17,26]
22	Weather & associated conditions in construction related risks.	Likely (3)	Very High (4)	3 × 4 =12	2	(Yadav, et al., 2021)[35,36]
23	Material and equipment sequencing, lifting errors and associated risks.	Very Likely (4)	Very High (4)	4 × 4 =16	1	(Moza & Paul, 2023) (Tayyab, et al., 2023)[14,15,30]
24	Prefabricated erection errors and associated risks.	Likely (3)	Very High (4)	3 × 4 =12	2	(Viswanathan & Jha, 2020)[31]
25	Flood, earthquake, tsunami, lightning and any other natural disaster risks.	Likely (3)	Very High (4)	3 × 4 =12	2	(Devika , et al., 2020) (Zhang, et al., 2018)[6]
26	Need of project, over feasibility related risks.	Highly Un Likely (1)	Very High (4)	1 × 4 =4	6	(Judson & Paul, 2022) (Wei, et al., n.d.)[8,32]
27	Poor sub surface investigation related risks	Un Likely (2)	Very High (4)	2 × 4 =8	4	(Pawar, et al., 2015)[21]
28	Strength related issues to structure.	Likely (3)	Very High (4)	3 × 4 =12	2	(Ajith, et al., 2019) (Zhang, et al., 2018)[2]
29	Deep excavation risks.	Very Likely (4)	Very High (4)	4 × 4 =16	1	(Chavan & Deshmukh, 2016)[4]

From the above matrix, it can be concluded that the topmost risks identified are risks related to vertical transportation and safety related risks. These two safety risks are works at height and vertical logistics. Works at height includes safety risks as temporary structure and platform risks, assumed vs. actual supports and connection risks, undisclosed changes risks. Vertical logistics & delivery includes safety risks as temporary hoist, tower cranes, erection related risks, wind

intensity, visibility problems and associated risks.

**Job safety analysis (JSA)** was prepared, based on the two number safety areas identified in these areas, total eight number activities were identified (four each). Safety hazards, risks were identified based on the literature studies. The job safety analysis format for safety risk identification and possible hazards involved in the safety activities for the safety areas identified are as shown below:

**Table 3: Job Safety Analysis Outcome Format, Source-Author.**

	<b>Description of safety area/ activity.</b>	<b>Activity based identified risks or possible hazards by student/ safety guideline as available in IS code/ standards/project HSE contracts/ organisation's safety plan/ safety policy.</b>
1	<b>Vertical delivery-Erection.</b>	Slip from hand. Structure collapse. Trip, slip hazards. Manual handling hazard. Ergonomic hazards. Sharp edges.
2	<b>Vertical delivery-Crane operation.</b>	Pre operational checks. Setup and positioning of the crane. Lifting operations. Lowering operations. Post-operation checks.
3	<b>Vertical delivery-hoist way operations.</b>	Inspect hoist way area. Set up hoist way access. Operate hoist way equipment. Monitor load during operation. Communicate with team. Perform emergency procedures. Complete operation and secure area.
4	<b>Vertical delivery-concrete pumping.</b>	Setting up the concrete pump, hoses and boom for the job. Operating the pump to move concrete to the required location. Ensuring the pump and equipment are functioning properly throughout operation. Performing routine checks and maintenance of equipment during and after operation. Positioning workers safely around the pump and concrete pour area. Cleaning the pump and hoses after use and demobilizing the equipment.
5	<b>Work at height-scaffolding &amp; platform works.</b>	Risk of falling while working on or around scaffolding. Scaffolding collapsing due to improper assembly or overloading. Contact with overhead power lines. Injuries from lifting and moving scaffolding components. Slippery surfaces due to rain or wind.
6	<b>Work at height-glazing works.</b>	Preparation and Setup. Review plans & specifications. Gather tools & materials. Set up work area and barriers. Material Handling. Transport glass panels. Store materials safely. Installation of Glass. Measure and cut glass as needed. Install glazing systems. Clean up work area, dispose of waste materials
7	<b>Work at Height-fall protection.</b>	Personal protective equipment. Safety equipment. Training requirement. Fall hazard. Equipment hazard. Personal hazard.
8	<b>Work at height-working on elevated platform.</b>	Erecting scaffolding, positioning elevated work platforms and inspecting for structural integrity. Performing tasks. Transporting or lifting tools, materials, or equipment onto the platform. Cleaning, maintaining the platform after use.

## RESEARCH METHODOLOGY

The research methodology followed is mentioned further as:

1. Identified the critical safety risks related to work at height and vertical logistics for high rise buildings (above G+15). Literature study was conducted with past research papers, dissertation, thesis works, codes and standards, to identified all risks from literature study. A questionnaire survey was prepared from experts & list ranking by RII (relative importance index) technique from industry professional and safety experts, found safety risks ranking through questionnaire survey from experts. Studied all risks related to those top 08 number safety risks belonging to 02 safety areas, as due to time limitation it was not possible to

take up with all the 29 number identified safety risks. Prepare questionnaire survey from experts & list ranking by RII (relative importance index) technique.

2. Identified and visited case study sites, collected data and filled checklists. Performed job safety analysis (JSA) for critical safety risk activities related to identified safety risk area with comparison to site data was done with previous literature data and found out gaps.
3. Analysed gaps and site issues, found out probable reasons and suggested corresponding mitigation strategies. Performed expert interviews with experts from varied background working directly or indirectly in safety and project execution domains in

various capacities. Validated the gaps and mitigation strategies by experts through personal interviews. Further, reconciled the results, compiled the final outcome and conclusion.

## RESULTS AND DISCUSSIONS

Primary case studies, site visits, data analysis were taken in following manner as follows:

1. The safety data collected for 03 number of sites for 03 months has near about no or less than 05 number for about of one lakh man hours worked in the months by all kinds of personnel's & staff at site.
2. For per million safe man hours negligible reporting of unsafe act, unsafe condition, first-aid cases, near-

miss, LTI, incident, accident and time lost due to safety reasons.

3. Although the work is being carried out as per the safety plan and all safety compliances to the extent possible is taken care of, still the reporting of incidents, near misses reporting is considerably lesser than actual. As reporting is less, compliances is also on the lesser side.

The primary case study projects are as follows:

1. Migsun Mignettee, Raj Nagar Extension, Ghaziabad, U.P.
2. Gulmohur Nest, Raj Nagar Extension, Ghaziabad, U.P.
3. Mangal Heights, Raj Nagar Extension, Ghaziabad, U.P.



**Fig. 1:** Under construction High rise Project Mangal heights, Ghaziabad.



**Fig. 2:** Under construction High rise Project, Migsun Mignettee, Ghaziabad, Source: Author.



*Fig. 3: Under construction High rise Project Gulmohur, Ghaziabad, Source- Author.*

### CASE STUDY PROJECT DETAILS



*Fig. 4: Migsun Mignettee Project's Site Plan, Source: UP Rera*



*Fig. 5: Gulmohur Nest, Project's Site Plan, Source: UP Rera.*



*Fig. 6: Mangal Heights, Project's Site Plan, Source: UP Rera.*

## CONSTRUCTION SAFETY INSPECTION RESULTS

*Table 4: Construction Safety Inspection Results, Source-Author.*

Construction safety inspection done based on job safety analysis and results recorded.										
		Migsun Mignettee			Gulmohur Nest			Mangal Heights		
		Yes	No	N/A	Yes	No	N/A	Yes	No	N/A
<b>1</b>	<b>Vertical Delivery- Crane Operation Safety Risks</b>									
1	Annual inspections complete.	Yes			Yes			Yes		
2	Operators tested and their physical exams recent.		No			No			No	
3	Daily inspections by operators.	Yes			Yes			Yes		
4	Outriggers used.									
5	Power lines removed and warning signs posted.	Yes					N/A			N/A
6	Lifting plan by competent engineer.		No			No			No	
7	Proper loading for capacity at lifting radius.				Yes					
8	Equipment operated in accordance with manufacturer's instructions.	Yes			Yes					N/A
9	Competent person inspect crane.	Yes			Yes			Yes		
10	Equipment properly maintained.	Yes			Yes				No	
11	Load testing accomplished.	Yes			Yes			Yes		
12	Signal workers placed at required positions.	Yes			Yes			Yes		
13	Alarms working and audible.		No		Yes			Yes		
14	Cranes and hoisting equipment inspected before each use to ensure safe working condition.		No			No			No	
15	All crane operators and riggers holding valid certifications and undergo ongoing training.	Yes			Yes				No	
16	SOP in place for establishing exclusion zones around crane operation areas to prevent unauthorized access during lifting operations.		No			No			No	
17	Communication established between crane operators and ground personnel.	Yes			Yes			Yes		
<b>2</b>	<b>Vertical Delivery- Hoist Way Operation Safety Risks</b>									
1	Annual inspections completed.	Yes			Yes					N/A
2	Operators been properly tested and their physical exams current.	Yes			Yes					N/A
3	Daily inspections completed by operators.	Yes			Yes					N/A
4	Hoists designed lifting plan by a competent engineer.		No			No				N/A
5	Equipment operated in accordance with the manufacturer's instructions.	Yes			Yes					N/A
6	Alarms working and audible.	Yes			Yes					N/A
7	Hoist operators certified and properly trained.		No			No				N/A
8	Hoist inspected before each use to ensure it is in good working condition.	Yes			Yes					N/A

<b>3</b>	<b>Vertical Delivery- Erection Related Safety Risks</b>									
1	Regular inspection and maintenance performed.	Yes			Yes			Yes		
2	Seat belts provided and used in equipment with rollover protection structure.	Yes			Yes			Yes		
3	Back moving alarms working and audible.	Yes			Yes			Yes		
4	Employees riding equipment with proper seating.	Yes			Yes			Yes		
5	Lights, brakes and warning signals operative.	Yes			Yes			Yes		
6	Equipment properly secured when not in use.	Yes			Yes			Yes		
7	Noise arresters used.		No			No			No	
<b>4</b>	<b>Vertical Delivery- General Construction Site</b>									
1	Posters and safety signs or warnings in place.		No			No			No	
2	Safety meetings held periodically.	Yes			Yes			Yes		
3	First aid kit available and adequately stocked.	Yes			Yes			Yes		
4	Accident reporting procedure been established.		No			No			No	
5	Emergency telephone numbers posted.	Yes			Yes			Yes		
6	Procedures to handle hazardous waste.	Yes			Yes			Yes		
7	Work area generally neat and clean.		No			No		Yes		
8	Passageways and walkways clear.	Yes			Yes			Yes		
9	Work area well lighted.	Yes			Yes			Yes		
10	Adequate potable water supply.	Yes			Yes			Yes		
11	Safety data sheets on file and readily available.		No			No			No	
12	Emergency rescue plans established and available.		No			No			No	
13	Appropriate personal protective equipment provided and used by all workers.	Yes			Yes			Yes		
14	Safety risk assessments conducted regularly to identify new or emerging hazards.	Yes			Yes			Yes		
15	Clear roles and responsibilities outlined for safety management, including a designated safety team.	Yes				No			No	
16	Safety plan easily accessible to all workers and stakeholders.		No			No			No	
<b>5</b>	<b>Works at Height- Scaffolding Safety Risks</b>									
1	Erecting the scaffold properly supervised.		No			No			No	
2	All structural members free from defects.	Yes			Yes			Yes		
3	All scaffold connections secured.	Yes			Yes			Yes		
4	Scaffolds erected on solid footing.		No			No			No	
5	Scaffold tied to structure.	Yes			Yes			Yes		

6	Working areas free of dirt, debris and grease.	Yes			Yes			Yes		
7	Guard rails, intermediate rails and toe boards in place.	Yes			Yes			Yes		
8	Ropes and cables in good condition.	Yes			Yes			Yes		
9	Fall protection available and in use.		No			No			No	
10	Workers trained in scaffold safety and usage.	Yes			Yes			Yes		
11	Scaffolds checked daily for safety, particularly after adverse weather conditions.	Yes			Yes			Yes		
12	Ladders used safely and inspected regularly.		No			No			No	
6	<b>Works at Height- Glazing Works Safety Risks</b>									
1	Floor openings planked over or barricaded.	Yes			Yes				No	
2	Workers wear personal fall protection equipment for working at heights.	Yes			Yes			Yes		
3	Guardrails, safety nets or other fall prevention systems in place for elevated work platforms.	Yes			Yes			Yes		
4	Fall arrest systems mandatory for all workers working at heights.	Yes			Yes			Yes		
5	Workers been trained on the proper use of fall protection equipment.	Yes			Yes			Yes		
6	Materials and tools secured on elevated surfaces to prevent them from falling.		No			No			No	
7	Designated exclusion zone below elevated work areas where objects are being hoisted.		No			No			No	
8	Workers below elevated platforms wearing hard hats to protect against falling objects.	Yes			Yes			Yes		
9	Guardrails and fall arrest systems in place on scaffolds, elevated platforms to prevent falls.	Yes			Yes			Yes		
10	Workers required to use fall arrest systems when working at heights above a specific threshold.	Yes			Yes			Yes		
7	<b>Works at Height- Fall Protection Safety Risks</b>									
1	Hazard evaluations been performed and certified.	Yes			Yes			Yes		
2	Employees issued PPE.	Yes			Yes			Yes		
3	Employees trained in the use of PPE.	Yes			Yes			Yes		
4	Inspections being conducted before and after use of PPE.		No			No			No	
5	Eye protection available.		No			No			No	
6	Face protection available.		No			No			No	
7	Hearing protection available.		No			No			No	
8	Respirators and masks provided.		No			No			No	
9	Head protection available.	Yes			Yes			Yes		
10	Hand and foot protection available.	Yes			Yes			Yes		

11	Physical exams performed as required.	Yes			Yes			Yes	
12	Designated exclusion zones on the ground below elevated work areas where materials are hoisted.		No			No		No	
13	Clear procedure for hoisting materials to higher levels, ensuring they are properly secured during the process.		No			No		No	

### The Deficiency Observed and its Inferences at all the Three Sites are as Mentioned Below

For **Cranes operations**, it was found that, operators' physical exams were not current, cranes and hoisting equipment not inspected before each use to ensure they are in safe working condition, procedure were not in place for establishing exclusion zones around crane operation areas to prevent unauthorized access during lifting operations. For **hoist way operations**, it was found that hoists were not designed lifting plan by a competent engineer, hoist operators weren't certified and properly trained, further for erection, noise arresters weren't used. For **Scaffoldings**, erecting the scaffolds weren't properly supervised, scaffolds weren't erected on solid footing, fall protection weren't available and not in use, ladders weren't used safely and not inspected regularly. For **glazing works**,

materials and tools weren't secured on elevated surfaces to prevent them from falling, designated exclusion zone below elevated work areas weren't where objects are being hoisted. For **fall protection**, inspections weren't being conducted before and after use of PPE, hearing protection weren't available, respirators and masks weren't provided, designated exclusion zones on the ground below elevated work areas weren't provided where materials were being hoisted, no clear procedure for hoisting materials to higher levels, ensuring they are properly secured during the process. For **general construction site**, accident reporting procedure hasn't been established, safety data sheets weren't on file and readily available, emergency rescue plans weren't established and available, safety plan weren't easily accessible to all workers and stakeholders.

Consolidated Safety Statistics Report																
Month: June-2024																
Sr. No.	Name of Site	Induction Training		Tool Box Talk		Total No. of Days Worked	Days Without Incident	Days With Incident	Days With Accident	Days With Unsafe Act / Unsafe Condition	First Aid Cases	Near Miss	LTI	Incident	Time lost due to Safety Reason	Consolidate Safe Man-Hours of The Month
		No. of Induction	No. of Induction	No. of Attendance	No. of Attendance											
1	Miglus Mignettee, Chasabad.	1	2	30	540	30	30	30	-	2	0	0	0	0	0	7200
2	Gulmohr Nest, Chasabad.	4	12	30	630	30	30	30	-	2	0	0	0	1	0	7200
3	Mangal Heights, Chasabad.	4	10	29	680	29	29	29	-	4	0	0	0	0	0	7200
		9	24	89	1250	89	89	89	-	6	0	0	0	1	0	21600
Month: July-2023																
1	Miglus Mignettee, Chasabad.	0	0	29	228	29	29	29	-	0	0	0	0	0	0	7200
2	Gulmohr Nest, Chasabad.	1	2	30	630	31	31	31	-	1	0	0	0	0	0	7200
3	Mangal Heights, Chasabad.	7	19	31	783	31	31	31	-	0	0	0	0	0	0	7200
		8	21	90	1641	91	91	91	-	1	0	0	0	0	0	21600
Month: August-2024																
1	Miglus Mignettee, Chasabad.	0	0	30	179	30	30	30	-	0	0	0	0	0	0	7200
2	Gulmohr Nest, Chasabad.	1	5	30	297	30	30	30	-	0	0	0	0	0	0	7200
3	Mangal Heights, Chasabad.	2	8	38	791	31	29	29	-	0	0	0	0	0	0	7200
		3	13	98	1267	91	89	89	-	0	0	0	0	0	0	21600

Fig. 1: Consolidated Safety Statistics Report of Case Studies, Source: Author.

**Primary Case Studies, Site Visits, Data Analysis Outcomes and Inferences**

Mitigation strategies as listed by author and validated by various safety experts through interviews are as follows:

1. Subletting the works to subcontractors- After subletting the works either the main contractor or construction company are not too bothered or transfers the entire safety to sub- contractors and indemnifies themselves. Hence there are need to enhance the safety plan for the said sub letted works considering the shared safety responsibility of both main contractors and subcontractors.
2. For equipment's selected, maximum defects are for older equipment's, having lesser AMC.
3. Not recording safety data activity wise, hence activity wise data recording is required for better control leading to safety issues, delays and cost escalation later.
4. Gap in the training versus actual reporting at site for safety reporting of near misses, incidents and accidents.
5. Not properly recording near misses, incidents and accidents. There is a gap in the training versus actual reporting at site, for training it is being done in lesser quantum and recorded more, whereas for safety reporting, near misses, incidents, accidents are happening more but are been reported in lesser quantum.
6. Generation of dummy data and tampering with actual recorded data to fulfil statutory compliances. To maintain and meet the stringent safety prequalification in other projects, safety data were settled and kind of under reporting is performed.
7. Gap's in site stakeholder coordination between safety manager, the execution manager and execution vendors.
8. Lacking's or gaps there in coordination between safety manager, the execution manager and execution vendor agency specialised personnel for operation for monitoring and control and missing links.

**Proposed Mitigation Measures Finalised after Expert Interview**

Inferences and mitigation strategies listed data were validated by expert's interview from varied background working directly or indirectly in safety and project execution domains in various capacities as follows:

1. Prequalification Criteria to be linked to safety aspects as well. In prequalification criteria, mandatory weightages to be given for safety risks in high rise construction projects for selection of contractors or subcontractors.
2. Component of safety to be added in item's rate for religious safety compliances. Resources and cost may be reviewed for inclusion in rate analysis of high execution risk items i.e. works at height and vertical delivery, so that contractor/subcontractor have inbuilt amounts for safety rather than cutting overheads and profits for safety compliances.
3. Mechanization of hazardous activity. Mechanization of hazardous activity shall be done as far as possible to reduce the direct risks involved.
4. Safety Process Improvements. Improved process improvement, the process required for safer execution of the work may be improved rigour sly as the project progresses.
5. Penalty for non-compliance of Safety Norms. Internal penalty for non-compliance of safety norms as mentioned in the HSE contracts of projects strictly for adherence at a mass scale.
6. Minimize the hazard/ substitute the material or equipment, isolate the hazard & its further substitution by lesser riskier processes or activities.
7. Unsafe acts shall be minimized by staff selection, training and unsafe conditions shall be minimised by organisation's interventions.
8. Substitution of riskier processes by lesser riskier processes.

9. Sensitive reporting of near misses, unsafe act, unsafe condition, first-aid cases, near-miss, LTI, incident & accidents is required at high rise construction sites by concerned officials and vetted by competent authority.

10. Insurances and all risks policy having safety aspects inbuilt. Insurances and timely renewal of man, material and machineries in the form of all risks policy shall be maintained having critical safety aspects inbuilt.

11. Implementing fully monitored engineering controls. Implementing fully monitored engineering controls are required to be monitored at an advanced level.

12. Implementing more stringent administrative controls. implementing more stringent administrative controls-work stoppages for non-conformances.

13. Enhanced external audits, strict compliances and external audit is required to be increased.

14. Overhead and contingency planning for safety & emergency rescue readiness, planning shall be done.

15. Enhancing health and safety consciousness and education among all the stakeholders from bottom to top.

## CONCLUSION

Construction is a complex activity and construction activities are always hazardous in many manners which poses a significant risk pertaining to safety of man, material and machines along with the health of the people employed in a construction project site. The unique climate, height, and materials involved in high-rise construction projects make them complicated and pose serious safety risks. Safety being one of the apex importance in high rise construction projects. Safety aspects related to vertical delivery of material, equipment, labour, pumping of concrete, modern formwork system issues, tower cranes, hoist ways operation and emergency evacuation for high rise

construction projects are the most important ones. Further, after the research study conducted as mentioned above for safety risks in high rise projects, going through various published and non-published works, codes and standards data collected from various sites, expert interviews, it was found that there are gaps in reporting and compliances for safety related issues due to various reasons.

As a way forward further research can be done to materialise the KPI's evolved as mitigation strategies for high rise construction projects. Also the study was based on building as considered high rise building up to a maximum height of 250 meters only as per the provisions given in IS code 16700. Any tall, super tall building above the height of 250 meters has not been considered in the purview of this research work. The study was limited to Indian context only, which can further be broaden up to global context.

## REFERENCES

1. Mishra, S. Safety related webinars- Webinar on construction safety. Department of Civil Engineering, IIT Kanpur. NPTEL (Principles of Construction Management Series).
2. Ajith, S., Sivapragasam, C., & Arumugaprabu, V. (2019). Quantification of risk and assessment of key safety factors for safe workplace in Indian building construction sites. *Asian Journal of Civil Engineering*, 20(5), 693-702.
3. Chauhan, C. S., Bhavsar, A. N., & Pitroda, J. R. (2022). Challenges in high-rise building projects for parameters of project management: A review. *International Research Journal of Engineering and Technology*.
4. Chavan, N., & Deshmukh, S. S. (2016). Challenges in construction of high-rise buildings in India.

5. Chouksey, M. R., Paul, P. D. V. K., Basu, D. C., & Bawania, M. V. (2020). Pre-construction measures to prevent delay in construction of residential high-rise projects. *International Journal of Creative Research Thoughts (IJCRT)*, 8(7), 3362-3374.
6. Devika, N., Basu, D. C., Seth, V., & Paul, D. V. K. (2020). Framework for assessment of climate change related risks to buildings. *International Journal of Engineering Research & Technology (IJERT)*, 9(09), September.
7. Judson, L., & Paul, K. V. (2022). Known uncertainty factors affecting building construction project cost. *NICMAR-Journal of Construction Management*, 37(4), 243-253.
8. Judson, L., & Paul, V. K. (2022). Critical uncertainty factors impacting building construction projects in India. *Civil Engineering and Architecture*, 10(5), 1854-1863.
9. Kumar Mishra, A., Aithal, P. S., Professor, A., & Bhandari Memorial Academy Nepal, M. (2021). Operational risk analysis of common activities of building construction projects.
10. Kumar, A., & Singhal, A. High rise SKY Towers, Mumbai—Construction challenges.
11. Kumar, K., & Paul, V. K. (2022). Risk and reliability assessment of smoke control systems in buildings. *International Journal for Research in Applied Science and Engineering Technology*, 10.
12. Maheshwari, U. Safety related webinars- Webinar on safety in construction. Department of Civil Engineering, IIT Delhi. NPTEL- Safety in Construction Series.
13. Maiti, J. Safety related webinars- Webinar on safety & risk management. Department of Industrial Engineering, IIT Kharagpur. NPTEL- Safety & Risk Analysis.
14. Moza, A., & Paul, V. (2023). Critical delay factors affecting construction project performance—A contemporary perspective. *European Project Management Journal*, 14.
15. Moza, A., & Paul, V. K. (2024). Critical success factors affecting project success in construction projects: A contemporary Indian perspective. *Journal of Project Management*, 9(3).
16. Muritala, O. U., Okwandu, A. C., & Akande, D. O. (2024). Impact of effective schedule management on high-rise building projects. *International Journal of Applied Research in Social Sciences*, 7(6), 1371-1386.
17. Nayal, D., Paul, P. D. V. K., & K. (2020). Selection of tower crane using multi-criteria decision-making techniques. *International Journal of Engineering Research & Technology (IJER)*, 9(5).
18. Patel, U. I., & Pitroda, J. R. Risk analysis and mitigation techniques in high rise buildings: A review.
19. Paul, V., & Khursheed, S. (2016). Cost modeling of an RCC residential building with and without soft story in Zone-IV (India). *International Research Journal of Engineering and Technology*, 3(9), 1264-1275.
20. Paul, V., Khursheed, S., & Jain, S. (2017). Benefit cost analysis of self-compacting concrete over conventional reinforced cement concrete. *International Journal of Research in Engineering and Technology*, 6(3), 2319-1163.
21. Pawar, C. S., Jain, S. S., & Patil, J. R. (2015). Risk management in infrastructure projects in India.
22. Prakash Giri, O. A., Dhakal, D. B., Koirala, M. C., & Poddar, S. D. Occupational risk assessment of high-rise building construction projects. *Tec Empresarial*, 189-199.

23. Rastogi, A., & Paul, V. (2019). Investigating the impact of non-load bearing (NLB) walls on the built-up area and dead load in multi-storeyed residential buildings. *Proceedings of the 12th International Conference of Faculty of Architecture Research Unit (FARU), University of Moratuwa.*
24. Sanni-Anibire, M. O., Mahmoud, A. S., Hassanain, M. A., & Salami, B. A. (2020). A risk assessment approach for enhancing construction safety performance. *Safety Science*, 121, 15-29.
25. Sidana, A. V. S. M., V. S. M. (Retd.), M. G. T. T., & Paul, V. K. (2022). A value approach for home buyers in township projects. *International Journal for Research in Applied Science & Engineering Technology*, 10(8).
26. Subramanyan, H., Priyadarshi, S., Sawant, H., & Bhatt, V. (2012). Construction project risk assessment: Development of model based on investigation of opinion of construction project experts from India.
27. Supraja, T. M. Safety audit and safety practices in construction. *IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)*, 17(5), 1-12.
28. Swaroop Devaiah, K. L., & Keshav, V. (2022). Application of BIM for effective construction safety management in high rise buildings. *IOP Conference Series: Materials Science and Engineering*, 9, 1255(1), 012006.
29. Tabish, S. Z. S., & Jha, K. N. Success factors for safety performance in public construction projects.
30. Tayyab, M., et al. (2023). A study on factors influencing cost overrun in high-rise building construction across India. *Journal of Smart Buildings and Construction Technology*, 5(1), 52-83.
31. Viswanathan, S. K., & Jha, K. N. (2020). Critical risk factors in international construction projects: An Indian perspective. *Engineering, Construction and Architectural Management*, 27(5), 1169-1190.
32. Wei, Y., et al. Vertical delivery challenges for high-rise building construction.
33. Yadav, P. S., & Paul, V. K. (2023). Project complexity management: Research trends and the way forward. *International Journal of Indian Culture and Business Management*.
34. Yadav, P. S., & Paul, V. K. (2020). Complexities of cost overrun in construction projects. *International Journal of Innovative Science and Research Technology*, 5(2), 768-771.
35. Yadav, P. S., & Paul, V. K. (2023). Investigating the determinants of construction project complexity impacting project success: An India perspective. *International Journal of Construction Management*.
36. Yadav, S. S., Edwards, P., & Porter, J. (2021). The incidence of construction site injuries to women in Delhi: A capture-recapture study. *BMC Public Health*, 21(1).
37. Zhang, K., et al. (2018). Significant progress in construction equipment of super high-rise buildings. *International Journal of High-Rise Buildings*, 7(3), 243-253.
38. Zhang, Z., & Pan, W. (2021). Multi-criteria decision analysis for tower crane layout planning in high-rise modular integrated construction. *Automation in Construction*, 127.