Factor That Affect Safety of Tower Crane in Construction Projects

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Abstract— **Tower cranes play a pivotal role in modern construction projects, enabling the efficient handling of heavy loads and materials. However, their operation poses significant safety challenges due to their size, complexity, and integration into dynamic construction environments. This study explores the key factors influencing the safety of tower cranes, focusing on technical, environmental, and human aspects. Technical factors include crane design, maintenance practices, and the reliability of safety mechanisms. Environmental conditions, such as wind speed, ground stability, and weather, also play a critical role in operational safety. Additionally, human factors, including operator training, compliance with safety regulations, and effective communication among site personnel, significantly impact risk levels.**

The aim of this paper is to investigate factors that contribute to accidents during tower crane installation/dismantling. Accident analysis and focus group interviews (FGIs) were conducted with people involved in crane work. Accidents occurring during installation/dismantling of tower cranes accounted for 68.4% of all fatal accidents. Accident analysis identified "Not following work procedures" as one of the main causes of these accidents, followed by "unsafe acts of workers." The FGIs investigation revealed the following factors that adversely affected the safety of the tower crane installation/dismantling: competence of the workers; roles of stakeholders such as principal contractors in the tasks; deterioration of tower crane components; and working conditions for conducting the tasks.

By analyzing accidents and near-miss incidents, this research identifies common hazards and provides actionable recommendations to enhance safety protocols. The findings emphasize the need for comprehensive safety management systems, regular inspections, and continuous training to mitigate risks and ensure the safe and efficient operation of tower cranes on construction sites.

Keywords: Tower cranes, safety, construction, Accidents, risks.

I. INTRODUCTION

Tower cranes are essential to modern construction, particularly in urban environments like Hyderabad, where high-rise buildings and large-scale infrastructure projects are common. Given their size and the significant loads, they handle, the safety of tower cranes is paramount to prevent accidents and ensure smooth project execution.

The safety of tower cranes in Hyderabad is influenced by a range of factors, including local environmental conditions, site-specific challenges, and regulatory requirements. The city's unique climate, with its hot summers, monsoon rains, and occasional high winds, adds complexity to crane operation and stability. Additionally, the diverse soil conditions and rapid urban development in Hyderabad require careful planning and continuous oversight.

This introduction aims to outline the key factors affecting the safety of tower cranes in Hyderabad, emphasizing the need for meticulous attention to site conditions, crane maintenance, operator training, load management, and regulatory compliance. By addressing these factors, construction professionals can enhance the safety and efficiency of crane operations, thereby reducing risks and ensuring the successful completion of construction projects.

Tower cranes are a critical component of modern construction projects, playing a vital role in lifting and placing heavy materials, equipment, and even building components. However, their operation poses significant safety risks to workers, the general public,

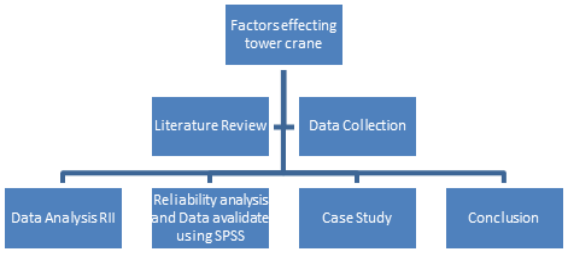
and the environment. Ensuring the safety of tower cranes is crucial to preventing accidents, protecting human life and property, and avoiding costly delays and reputational damage.

The safety of tower cranes in construction projects is influenced by a complex array of factors, which can be broadly categorized into human, technical, and environmental factors. These factors are interconnected and can have a compounding impact on safety.

II-OBJECTIVE

1. To identify the safety factors involving tower crane in various construction projects.
2. To identify the critical factors using Relative Importance Index (RII) method in tower crane safety factors.
3. To identify the most important factors by using SPSS (factor analysis method)
4. To suggest various ways to reduce the accidents in tower crane safety in construction projects.

III. METHODOLOGY



a. DATA COLLECTION

A Questionnaire is a method of data collection through different means of interview such as telephone, email, personal interview, etc. for this study, a questionnaire is a list of questions prepared through which the respondent must respond. A well design questionnaire will encourage responders to provide accurate and full information. A questionnaire is designed using google forms which is then distributed among different contractors, civil engineers site engineers, etc. for gathering information. For designing questionnaire, a five likert scale as shown in fig.

Options	score
Strongly Agree	1
Agree	2
Neutral	3
Disagree	4
Strongly Disagree	5

Table.no.1 A five likert scale

The questionnaire in this context was prepared and is shown in Appendix (2) After designing

of Questionnaire. it is to be verified by Professional Experts, and Project Guide, and Project coordinator with their attestation to proceed with Distribution among various contractors.

Responses should be tracked down and data collected is to be analyzed to find the processes which are Empirical in Nature. To make data more accurate, only Qualified and Experienced staff are to be selected among managing staff depending on their years of experience and position or role in the company or organization.

Classification of Factors

The 32 factors were further divided into 4 types namely:

1) Human Factors.
2) Environmental Factors.
3) Organizational Factors.
4) Equipment factor

Top 10 ranking factors:

Top factors	RII	Rank
Operator training	0.8366	1
Lack of routine inspection	0.8316	2
Over loading	0.8301	3
Poor lubrication	0.825	4
Mechanical failure	0.8166	5
Stress and Pressure	0.802	6
High wind speed	0.7933	7
Temperature	0.7833	8
Lack of safety	0.775	9
Poor planning and coordination	0.7688	10

Table.no. 2 Top 10 ranking factors

C. Reliability Analysis

Reliability is a factor when variables are constructed from the summed measures and utilized as predictor components in objective models. It is crucial to determine whether the same set of items would elicit the same responses if the queries were reworked and resubmitted to the same respondents. The researcher

declares these test instrument-derived variables as reliable only when they consistently produce consistent and dependable responses during the test administration.

Cronbach's alpha coefficient is the most frequently employed internal consistency index. The reliability of this index is between 0 and 1, with a reliability of 0 indicating no relationship and a reliability of 1 indicating a flawless and positive relationship. The inquiries would be designed to be concise, as reliability decreases as the length of the questions increases.

Internal consistency procedures are based on the principle that queries that measure the same phenomenon should produce comparable. results. A single measuring instrument is administered to a group of individuals on a single occasion in order to estimate reliability in the inner consistency estimate procedure. The questionnaire's overall consistency was

Reliability Statistics (All factors)	
Cronbach's Alpha	N of Items
0.857	32

Table no 3 Reliability estimates

Cronbach's alpha	Internal consistency
0.8> a >0.7	Acceptable
0.7> a>0.6	Questionable
0.6> a>0.5	Poor
0.5 > a	Unacceptable
a>0.9	Excellent
0.9 > a>0.8	Good

S.P.S.S

IBM SPSS Statistics is a software suite that is specifically intended for the purpose of conducting statistical analyses. It provides instruments and functionalities for the analysis, administration, and reporting of data. SPSS is extensively employed in a variety of fields, including social sciences, business, marketing, and healthcare, to facilitate data analysis and the extraction of valuable insights. SPSS allows users to conduct a wide range of statistical analysis, including descriptive statistics, inferential statistics, regression analysis, factor analysis, cluster analysis, and other techniques. Furthermore, it offers capabilities for data visualization, manipulation, and transformation. SPSS is distinguished by its user-friendly graphical interface, which allows individuals without advanced programming skills to effortlessly operate the software. Users are able to conduct research by selecting options from menus and dialog windows, which eliminates the necessity of writing code. IBM SPSS Statistics has evolved significantly over time, integrating seamlessly with a variety of data sources and technologies and implementing sophisticated analytics. It has been extensively employed in academic research, market research, corporate analytics, and other fields where data analysis is essential for decision-making. SPSS facilitates the importation of data from a variety of sources, such as databases, Excel spreadsheets, and other formats utilized in statistical tools. Furthermore, SPSs provides the ability to manage missing values, recode variables, and transform data, as well as to perform data cleaning and preparation duties. SPSS tools are employed to calculate statistical measures that summarize the data, including measures of central tendency (such as mean, median, and mode) and measures of dispersion (such as standard deviation and range), in the context of descriptive analysis of data. Frequency distributions, cross-tabulations, and summary tables can be generated through the application of a variety of statistical methods, which will enable you to gain a thorough and Succinct comprehension of your data. SPSS provides a wide range of inferential statistical studies, including t-tests, ANOVA (analysis of variance), regression analysis, chi-square tests, and other techniques. These studies aid in the identification of correlations, disparities and linkages in our data. Data Visualization: SPSS enables the creation of a wide range of charts and graphs to visually represent your data. Bar charts, pie charts, and histograms are examples off these visual representations. Among other things, scatter plots. The comprehension of patterns and trends in your data is facilitated by visualization tools. Custom Analysis: SPSS has the ability to generate custom analyses using its inherent syntax language if your analysis requires a specific statistical technique that is not readily accessible in the default menus. SPSS facilitates the development of sophisticated reports and presentations that present the findings of your investigation in a Professional manner. The effective communication of your findings to others can be achieved by incorporating tables, charts, and statistical data into your reports. Syntax Language, a proprietary scripting language in SPSS, allows users to automate and replicate analyses. This feature is particularly advantageous for the generation of standardized results and the execution of complex or recurring analyses. In addition to the fundamental product, SPSS offers extensions and add-ons that provide additional functionality and

capabilities. These extensions are appropriate for conducting targeted studies, visualizing data, and integrating with other software applications in a seamless manner. SPSS includes tools for both data mining and machine learning. To uncover patterns and acquire insights from the data, it is possible to employ a variety of methods, including clustering, factor analysis, and decision trees. Despite the fact that SPSS is frequently employed in the social sciences, it is also employed in a variety of other fields, including psychology, economics, healthcare, and market research. In order to conduct precise and significant analyses using SPSS, it is essential to have a thorough understanding of research procedures and statistics.

FACTOR ANALYSIS

Factor analysis is a statistical technique that uses statistics to investigate the relationships between observed variables and condense them into a more manageable set of unobserved factors. It is frequently implemented in a variety of domains, including economics, social sciences, psychology, and market research. Factor analysis aims to identify latent patterns or dimensions that explain the associations or variations among a collection of observed variables. Factor analysis initiates with the collection of data on a set of variables. These factors can be interconnected, for instance, through a series of survey inquiries that are designed to evaluate fundamental concepts such as IQ, personality traits, or customer satisfaction.

The process of factor analysis begins with the collection of data on a set of variables. These factors can be interconnected, for instance, through a series of survey ingquiries that are designed to evaluate fundamental concepts such as IQ, personality traits, or customer satisfaction. Factor analysis is designed to identify a diminished number of underlying factors that explain the observed relationships or associations between the variables. Principal Component Analysis (PCA) and Principal Axis Factoring (PAF) are among the numerous methodologies that can be implemented to extract factors. These strategies are designed to identify and isolate the components that account for the greatest amount of variation in the original data. Factor rotation is an optional procedure that simplifies the comprehension of the factors. The procedure involves the conversion of factor loadings, which are coefficients that illustrate the relationship between variables and factors, to simplify their interpretation. Varimax and Promax rotation are two rotation methods that are frequently employed. The researcher then proceeds to analyze and decipher the significance of the factors after the extraction and rotation procedure. Each component is a fundamental dimension or unobservable concept that can explain the observed relationships among the variables. The goal is to provide a substantial designation or explanation for each factor. Factor scores are numerical values that represent the performance or capabilities of individuals with respect to Of the identified factors. These scores can be employed to categorize individuals based on their factor scores or in subsequent investigations. Various fit indices, such as the Kaiser-Meyer-Olkin (KMO) measure and Bartlett's test of sphericity, can be employed to assess the adequacy of the factor model to the data. These indices are instrumental in evaluating the degree to which the factors are responsible for the variability in the data. Statistically significant (Sig.000) is the recommended value of 0.70, which indicates satisfactory sphericity in Bartlett's Test. This implies that the data is appropriate for factor analysis.

4.11 KMO and Bartlett's Test

The selected variables are tested and the outcome of the given variable is shown in table the result of KMO and Bartlett's Test with a value of 0.890. This says that data is correct for Factor Analysis

KMO and Bartlett's Test		
Kaiser- Meyer-Olkin Measure of sampling Adequacy.		0.872
Bartlett's test of Sphericity	Approx.chi-Square	088.598
	Df	0.499
	Sig.	.000

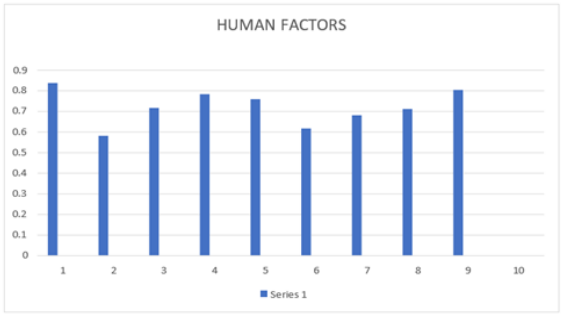
IV. RESULTS

The study used Relative Importance Index (RII) and Factor Analysis (SPSS) to identify and prioritize the critical factors affecting the safety of tower cranes in construction projects. A total of 80 valid responses were collected from experienced professionals in the construction industry in and around Hyderabad.

4.1 Human Factors

Top 3 Critical Human Factors:

Relative Importance Index:



Showing Comparison graph of Technical related factors based on RII

HUMAN FACTOR:

Factors	Name	RII	Rank
H1	Operator training	0.8366	1
H2	Experience level	0.58	8
H3	Fatigue	0.715	4
H4	Stress and pressure	0.782	3
H5	Lack of awareness	0.7583	9
H6	Miss communication	0.616	7
H7	Negligence	0.68	6
H8	Language barrier	0.71	5
H9	Compliance	0.803	2
	RII mean		

- Operator Training (RII: 0.8366) – most influential, indicating the necessity of formal, ongoing skill-based training.
- Compliance (RII: 0.803) – underscores the importance of adherence to safety protocols and regulations.
- Stress and Pressure (RII: 0.782) – highlights operational stress from time constraints or workload pressures.

4.2 Environmental Factors

Top 3 Environmental Factors:

- High Wind Speed (RII: 0.834) – most significant, directly impacts crane stability and operations.
- Extreme Temperatures (RII: 0.801) – affects worker performance and mechanical reliability.
- Ground Stability (RII: 0.7933) – foundational integrity is vital for safe crane erection and operation.

4.3 Organizational Factors

Top 3 Organizational Issues:

- Lack of Safety Culture (RII: 0.888) – highest-ranking organizational concern, reflecting a widespread deficiency in safety mindsets.
- Poor Planning and Coordination (RII: 0.8198) – indicates inefficiencies in project execution and logistics.
- Insufficient Toolbox Talks (RII: 0.7588) – signifies gaps in daily safety briefings and preparedness.

Factors	Name	RII	Rank
O1	Inadequate supervision and site management	0.6501	6
O2	Poor planning and coordination	0.8198	2
O3	Lack of safety culture	0.888	1
O4	Improper work scheduling	0.601	7
O5	Insufficient budget allocation	0.54811	8
O6	Poor risk assessment	0.6933	5
O7	Lack of emergency	0.7136	4
O8	Insufficient tool box	0.7588	3
	RII mean		

Showing RII mean of Organizational related factor

4.4 Equipment Factors

- Top 3 Equipment Issues:
- Lack of Routine Inspection & Maintenance (RII: 0.9132) – the single most critical factor overall.
- Overloading (RII: 0.9011) – reveals a frequent unsafe practice, possibly driven by poor risk evaluation.
- Poor Lubrication and Cleaning (RII: 0.8990) – affects operational efficiency and long-term equipment integrity.

V. CONCLUSION

Tower cranes are marvels of engineering, standing tall on the skylines of our cities, enabling the construction of structures that shape the future. Yet, behind every lift and every swing of the jib lies a complex interplay of risks, responsibilities, and real human

lives. This study has shown that the safety of tower crane operations hinges not only on machines and materials but also on the decisions, vigilance, and care of the people involved—from crane operators and riggers to site supervisors and engineers.

The key factors influencing safety—mechanical integrity, weather conditions, human error, site management, and regulatory compliance—are deeply interconnected. Mechanical failures often stem from neglected maintenance; human errors are sometimes the result of poor training or miscommunication; and environmental hazards are exacerbated by inadequate planning. Each incident or near-miss is not just a statistic—it represents someone's father, sister, coworker, or friend returning home safely or not.

Improving crane safety is not just a technical challenge—it is a moral imperative. It demands a culture of accountability, where inspections are not skipped, safety systems are not bypassed, and every voice on-site is empowered to speak up. It calls for investment in smarter technologies, more consistent training, and stronger regulatory enforcement—not as bureaucratic hurdles, but as life-saving standards.

Ultimately, a safe tower crane operation reflects a commitment to human life over deadlines and profits. By understanding the contributing factors in depth and acting on them with resolve, the construction industry can lift not only steel and concrete but also the standards of care and responsibility that every worker deserves.

REFERENCE

[1] Zhou, Z., Irizarry, J., & Li, Q. (2013). "Using BIM to support crane planning in building construction." *Automation in Construction*, 36, 95–101.

[2] Chan, D. W., et al. (2006). "An empirical survey of the safety climate in the Hong Kong construction industry." *Journal of Construction Research*, 7(2), 121–134.

[3] Abdelhamid, T. S., & Everett, J. G. (2000). "Identifying root causes of construction accidents." *Journal of Construction Engineering and Management*, 126(1), 52–60.

[4] Zhao, D., McCoy, A. P., & Kleiner, B. (2009). "Managing safety in crane operations using real-time location systems." *Journal of Construction Engineering and Management*, 135(10), 1029–1037.

[5] Yin, X., & Zhang, L. (2018). "Quantitative risk assessment of tower cranes using fault tree and Bayesian network methods." *Safety Science*, 110, 1–15.

[6] Bongiorno, R., et al. (2022). "Real-time monitoring of tower crane operations using IoT and computer vision." *Automation in Construction*, 138, 104252.

[7] Fang, D., et al. (2015). "Safety climate in construction: A review and future research directions." *International Journal of Project Management*, 33(4), 1016–1033.

[8] Martínez-Aires, M., et al. (2018). "Occupational safety in the construction industry—A review and outlook." *International Journal of Environmental Research and Public Health*, 15(3), 481.

[9] Yang, J., et al. (2012). "Risk assessment of tower crane operations based on fuzzy logic." *Journal of Safety Research*, 43(4), 307–315.

[10] Carter, G., & Smith, S. D. (2006). "Safety hazard identification on construction projects." *Journal of Construction Engineering and Management*, 132(2), 197–205.

[11] Hughes, P., & Ferrett, E. (2016). *Introduction to Health and Safety in Construction* (5th ed.). Routledge.

[12] Hinze, J. (2011). *Construction Safety* (2nd ed.). Prentice Hall.

[13] Bureau of Labor Statistics (2020). *Fatal Occupational Injuries Involving Cranes*. U.S. Department of Labor.

[14] HSE (Health and Safety Executive, UK) (2014). *Safe Use of Lifting Equipment (LOLER).* HSE Books.

[15] Fang, D., & Wu, H. (2013). *Construction Safety Management: Systems, Theories and Applications.* Wiley.