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Enhancing Safety in Tower Crane Installation and Dismantling: Key Factors to Consider in Construction Sites

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A B S T R A C T

Installation and dismantling of tower cranes in urban construction sites, while essential, pose significant risks, making them among the most perilous tasks in the construction industry. These processes are vital for erecting high-rise buildings and large apartment blocks, particularly in bustling downtown areas. However, they come with inherent dangers, leading to fatalities, project delays, and structural damage.

This paper delves into the factors contributing to accidents during tower crane installation and dismantling. Through accident analysis and focus group interviews (FGIs) involving crane personnel, it was found that a substantial portion (68.4%) of fatal accidents in construction sites stemmed from mishaps during these crane operations.

The primary cause identified through accident analysis was the failure to adhere to established work procedures, closely followed by unsafe actions by workers. FGIs further elucidated on factors exacerbating safety risks during tower crane installation and dismantling. These included the competence of workers involved, the responsibilities of key stakeholders like principal contractors, the integrity of crane components, and the prevailing work conditions.

These findings offer valuable insights for both regulators and practitioners seeking to enhance safety standards in tower crane operations. Regulators can utilize this information to refine existing safety protocols and introduce new regulations where necessary. Additionally, practitioners can implement measures to improve worker competence through training programs, enhance communication and collaboration among stakeholders, conduct regular inspections to detect component deterioration, and optimize working conditions to mitigate risks.

By addressing these factors proactively, stakeholders can work towards minimizing accidents during tower crane installation and dismantling, thereby safeguarding the lives of workers, preserving project timelines, and ensuring the integrity of construction endeavors. Installation and dismantling of tower cranes in urban construction sites, while essential, pose significant risks, making them among the most perilous tasks in the construction industry. These processes are vital for erecting high-rise buildings and large apartment blocks, particularly in bustling downtown areas. However, they come with inherent dangers, leading to fatalities, project delays, and structural damage.

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1. Introduction

Ensuring safety in tower crane installation and dismantling is paramount within the construction industry due to the significant risks involved. Tower cranes play a crucial role in the construction of high-rise buildings, large-scale apartment blocks, and other urban structures, especially in densely populated downtown areas. However, the installation and dismantling of these towering structures present inherent dangers that demand careful consideration and proactive measures to mitigate risks.

This paper aims to explore the various factors that influence the safety of tower crane installation and dismantling processes in construction sites. By delving into the root causes of accidents and analysing insights from focus group interviews (FGIs) with crane personnel, this study seeks to provide valuable insights for regulators, practitioners, and stakeholders involved in construction projects.

Tower crane installation and dismantling activities are not only complex but also time-sensitive, requiring meticulous planning and execution. Any lapses in safety protocols or deviations from established procedures can result in catastrophic consequences, including loss of life, project delays, and damage to property. Therefore, understanding the key factors that contribute to accidents during these operations is crucial for fostering a safer working environment and preventing avoidable tragedies.

The findings of this research shed light on several critical factors affecting the safety of tower crane installation and dismantling. These include adherence to work procedures, competence of workers involved, roles and responsibilities of stakeholders such as principal contractors, condition of crane components, and the overall working environment. By identifying these factors and understanding their implications, stakeholders can implement targeted interventions to enhance safety standards and mitigate risks effectively.

Ultimately, the insights gleaned from this study can inform the development of robust safety guidelines, training programs, and regulatory frameworks tailored to the specific challenges associated with tower crane operations. By prioritizing safety and adopting proactive measures, construction industry stakeholders can strive towards achieving safer work environments, protecting the well-being of workers, and ensuring the successful completion of construction projects.

2. Methodology

The study aims to assess the likelihood and impact of safety risk factors by gathering insights from practitioners directly involved in tower crane installation and dismantling processes, including safety managers, equipment managers, and team leaders. To achieve this, a questionnaire survey was employed due to its suitability for eliciting knowledge from industry experts. Given the absence of precise data regarding the population size of such practitioners, a sample size of 57 was determined using a minimum sample size table for an unknown population, ensuring a 95% confidence interval with a 5% error level.

The questionnaires were distributed across three major cities in Nigeria—Kaduna, Abuja, and Lagos—using purposive sampling, which targeted practitioners with relevant expertise and experience. However, only 38 completed questionnaires, accounting for 66.7% of the total distributed, were included in the analysis. Descriptive statistics were utilized to analyse the responses, and the findings were presented in tabular form for clarity.

This methodology was chosen to capture firsthand insights from practitioners who possess valuable on-the-ground experience and expertise in tower crane operations. By leveraging their knowledge, the study aimed to identify and prioritize safety risk factors, considering both their likelihood of occurrence and their potential impact on construction site safety.

Through this approach, the research seeks to contribute to the development of effective safety management strategies tailored specifically to the unique challenges associated with tower crane installation and dismantling. By incorporating insights from industry practitioners, the study aims to enhance safety protocols and minimize the occurrence of accidents, ultimately promoting safer working environments in the construction industry.

3.Analysis and Interpretation of Results

3.1Participant Demographics

This section provides an overview of the respondents' characteristics, including their job roles, educational qualifications, and years of experience, as summarized in Table 5.1.

Table 5.1 demonstrates a balanced representation across all respondent categories, with each group comprising approximately 30% or more of the total sample. Notably, safety managers are the most represented category, accounting for 36.8%, while equipment managers constitute the smallest group at 28.9%.

All respondents possess at least a post-secondary education, with 34.2% holding bachelor's degrees and 15.8% holding master's degrees. Additionally, Table 5.1 reveals that 34.2% of respondents have between 0-5 years

of experience in the field. However, a significant majority, totalling 65.8%, have accumulated at least 6 years of experience working with tower cranes. This level of experience is considered sufficient for making informed judgments and providing valuable insights into the subject matter.

Items	Frequency (No	Percentage (%)
Job Description		
Safety managers	14	36.8
Equipment managers	11	28.9
	13	34.2
Total	38	100
Education qualification		
ND	12	31.6
HND	7	18.4
Bachelors	13	34.2
MSc.	6	15.8
Total	38	100
Years of experience		
0-5	13	34.2
6-10	20	52.6
11-15	4	10.5
16-20	1	2.6
Total	38	100

Table 5.1 Participant Overview

3.2Assessment of Safety Risk Factor Probability

The likelihood of safety risk factors occurring during tower crane installation and dismantling was assessed by respondents using a five-point Likert scale, with mean values and standard deviations calculated to rank these factors. Table 5.2 presents these assessments, highlighting that "Abrasion (wear and tear of components such as bolts, nuts, or pins)" emerged as the most probable factor, with a mean value of 3.63, while "Incompatibility of components" ranked the lowest at 2.16. Notably, the first six factors in Table 5.2 had mean values ≥ 3.0, indicating a likelihood of occurrence with occasional recurrence, while factors from the 8th position to the 21st had mean values ≥ 2.0, suggesting a lower likelihood of recurrence but still possible occurrence.

Contrary to previous research indicating that failure to follow work procedures is the primary cause of accidents on construction sites, this study found "not following work procedure in manuals" ranking 12th, with a mean value of 2.89. This suggests an increased awareness and adherence to safety procedures during tower crane operations, potentially leading to improved safety consciousness among users.

The finding that "abrasion" is the most probable factor aligns with previous research emphasizing maintenance management as crucial for tower crane safety. This underscores the ongoing influence of maintenance practices on safety during installation, dismantling, and operation.

Interestingly, while operator proficiency is typically considered a major safety determinant, it ranked fourth in this study with a mean value of 3.18. This may indicate a reduced impact of operator experience on safety, possibly due to increased overall experience and familiarity with tower crane operations.

Moreover, the low ranking of "incompatibility of components" suggests continuous improvements by tower crane manufacturers in enhancing component compatibility. However, efforts are still needed to further mitigate this risk factor, albeit its less frequent occurrence.

In summary, the findings highlight the evolving safety landscape in tower crane operations, with increased awareness, improved maintenance practices, and advancements in component compatibility contributing to enhanced safety measures on construction sites.

S/ No	Safety Risk Factors	Frequency						Σfx (Σα)	Mean	Std. Dev.	Rank
		1	2	3	4	5	Σf				
1	Abrasion (wear and tear of components such as bolts, nuts, or pins).	0	9	9	7	13	38	138	3.63	1.19	1st
2	Fracture of a wire rope during dismantling.	0	5	19	9	5	38	128	3.37	0.88	2nd
3	Deterioration of tower crane's part (components).	3	4	11	19	1	38	125	3.29	0.98	3rd
4	Inexperienced tower crane operators.	0	14	6	15	3	38	121	3.18	1.04	4th
5	Lack of workers competence.	0	13	14	4	7	38	119	3.13	1.10	5th
6	Trying to finish the work earlier than the time required for safe work.	1	9	19	5	4	38	116	3.05	0.96	6th
7	Buckling of a telescopic cage.	1	9	22	3	3	38	112	2.95	0.87	7th
8	Frequently omitting required safety procedures or rules for various reasons.	4	5	20	8	1	38	111	2.92	0.94	8th

9	Failure of working platforms.	3	10	15	7	3	38	111	2.92	1.05	9th
10	Falling items.	2	13	14	4	5	38	111	2.92	1.10	10th
11	Not following work procedures in manuals for the installation/climbing/disantling of tower cranes.	4	5	21	7	1	38	110	2.89	0.92	11th
12	Contractors do not recognise the need to ensure the safety of tower crane installation and dismantling.	3	13	7	15	0	38	110	2.89	1.03	12th
13	Workers (erector, dismantler) are leaving the work often due to hard working condition.	5	11	15	3	4	38	104	2.74	1.13	13th
14	Insufficient number of workers to perform the work correctly and safely.	3	17	8	8	2	38	103	2.71	1.06	14th
15	Unreasonable sites condition (working space, ground conditions and restrictions).	1	19	13	4	1	38	99	2.61	0.82	15th
16	Time constraints requested from employer/principal contractor.	7	8	18	3	2	38	99	2.61	1.05	16th
17	Malfunction of a tower crane.	7	17	6	4	4	38	95	2.50	1.22	17th
18	Worker's attitude (installation/dismantling workers).	4	17	13	3	1	38	94	2.47	0.89	18th
19	Instruction and supervision at construction sites are insufficient.	10	12	11	3	2	38	89	2.34	1.12	19th
20	Overloading with objects exceeding the tower crane load limit.	5	21	11	1	0	38	84	2.21	0.70	20th
21	Incompatibility of components.	12	13	10	1	2	38	82	2.16	1.08	21st

Table 3.2 Likelihood of Safety Risk Factors

3.3 Impact Severity of Safety Risk Factors.

The severity of potential safety risks on construction sites was evaluated using a five-point Likert scale, with mean values derived to assess the degree of impact, as presented in Table 3.2.

Notably, "fracture of a wire rope during dismantling" ranked highest in impact severity, with a mean value of 4.63, indicating the potential for catastrophic outcomes such as fatality, major injuries, and critical property damage. Conversely, the factor concerning workers leaving work due to challenging conditions demonstrated the lowest impact severity, with a mean value of 2.34, suggesting a likelihood of minor injuries if it were to occur. However, all factors assessed in Table 5.2 exhibited impact severity ranging from minor injuries to fatalities, highlighting the importance of addressing each potential risk.

Interestingly, despite being the 20th most probable factor for occurrence, overloading tower cranes beyond their load limit ranked third in impact severity, with a mean value of 4.18. This discrepancy between probability and impact underscores the importance of considering both factors when assessing risk levels.

To further evaluate risk levels, a combined risk score was calculated using a standard risk rating, resulting in the Relative Significance Index Score (RSIS) presented in Table 5.4. "Fracture of a wire rope during dismantling" received the highest RSIS of 15.6, indicating a high-risk factor requiring stringent control measures to ensure a safe working environment. Factors ranked from 2nd to 15th displayed moderate risk levels, necessitating appropriate controls for mitigation. Conversely, factors ranked from 16th to 21st indicated low-risk levels, requiring no further action.

The disparity in risk perception regarding workers leaving work due to challenging conditions may be attributed to prevalent unemployment rates in the country, leading individuals to prioritize job retention despite adverse working conditions. Additionally, the high RSIS values for "fracture of a wire rope during dismantling" and "abrasion" underscore the importance of routine maintenance practices for tower cranes to minimize associated risks effectively.

S/No	Safety Risk Factors	Frequency						Σfx (Σβ)	Mean
		1	2	3	4	5	Σf		
1	Fracture of a wire rope during dismantling.	0	0	1	12	25	38	176	4.63
2	Not following work procedures in manuals for the installation/climbing/ dismantling of tower cranes.	0	1	8	10	19	38	161	4.24

3	Overloading with objects exceeding the tower crane load limit.	0	0	6	19	13	38	159	4.18
4	Frequently omitting required safety procedures or rules for various reasons.	0	2	9	10	17	38	156	4.11
5	Lack of workers competence.	0	3	8	12	15	38	153	4.03
6	Unreasonable sites condition (working space, ground conditions and restrictions).	0	2	10	12	14	38	152	4.00
7	Trying to finish the work earlier than the time required for safe work.	1	1	11	12	13	38	149	3.92
8	Inexperienced tower crane operators.	1	5	6	11	15	38	148	3.89
9	Deterioration of tower cranes part (components).	1	8	8	5	16	38	141	3.71
10	Abrasion (wear and tear of components such as bolts, nuts, or pins).	1	4	17	2	14	38	138	3.63
11	Malfunction of a tower crane.	1	3	16	8	10	38	137	3.61
12	Incompatibility of components.	1	11	5	9	12	38	134	3.53
13	Buckling of a telescopic cage.	0	8	9	16	5	38	132	3.47
14	Falling items.	1	8	9	18	2	38	126	3.32
15	Contractors do not recognise the need to ensure the safety of tower crane installation and dismantling.	1	10	13	6	8	38	124	3.26
16	Failure of working platforms.	5	6	7	15	5	38	123	3.24

17	Instruction and supervision at construction sites are insufficient.	5	6	13	10	4	38	116	3.05
18	Insufficient number of workers to perform the work correctly and safely.	5	2	23	7	1	38	111	2.92
19	Time constraints requested from employer/principal contractor.	2	16	10	9	1	38	105	2.76
20	Worker's attitude (installation/dismantling workers).	2	17	9	9	1	38	104	2.74
21	Workers (erector, dismantler) are leaving the work often due to hard working condition).	6	21	6	2	3	38	89	2.34

Table 3.3 Impact Severity Assessment

S/No.	Safety Risk Factors	Σα	Σβ	ΣRS	N	RSIS	Rank	Risk Level
1	Fracture of a wire rope during dismantling.	128	176	22528	1444	15.6	1st	High
2	Abrasion (wear and tear of components such as bolts, nuts, or pins).	138	138	19044	1444	13.2	2nd	Moderate
3	Lack of workers competence.	119	153	18207	1444	12.6	3rd	Moderate
4	Inexperienced tower crane operators.	121	148	17908	1444	12.4	4th	Moderate
5	Not following work procedures in manuals for the installation/climbing/dismantling of tower cranes.	110	161	17710	1444	12.3	5th	Moderate

6	Deterioration of tower crane's part (components).	125	141	17625	1444	12.2	6th	Moderate
7	Frequently omitting required safety procedures or rules for various reasons.	111	156	17316	1444	12.0	7th	Moderate
8	Trying to finish the work earlier than the time required for safe work.	116	149	17284	1444	12.0	8th	Moderate
9	Unreasonable sites condition (working space, ground conditions and restrictions).	99	152	15048	1444	10.4	9th	Moderate
10	Buckling of a telescopic cage.	112	132	14784	1444	10.2	10th	Moderate
11	Falling items.	111	126	13986	1444	9.7	11th	Moderate
12	Failure of working platforms.	111	123	13653	1444	9.5	12th	Moderate
13	Contractors do not recognise the need to ensure the safety of tower crane installation and dismantling.	110	124	13640	1444	9.4	13th	Moderate
14	Overloading with objects exceeding the tower crane load limit.	84	159	13356	1444	9.2	14th	Moderate
15	Malfunction of a tower crane.	95	137	13015	1444	9.0	15th	Moderate
16	Insufficient number of workers to perform the work correctly and safely.	103	111	11433	1444	7.9	16th	Low
17	Incompatibility of components.	82	134	10988	1444	7.6	17th	Low

18	Time constraints requested from employer/principal contractor.	99	105	10395	1444	7.2	18th	Low
19	Instruction and supervision at construction sites are insufficient.	89	116	10324	1444	7.1	19th	Low
20	Worker's attitude (installation/dismantling workers).	94	104	9776	1444	6.8	20th	Low
21	Workers (erector, dismantler) are leaving the work often due to hard working condition).	104	89	9256	1444	6.4	21st	Low

Table 3.4 Safety Risk Assessment

4.Tower Crane Maintenance, Inspection, and Comprehensive Examination.

4.1 MAINTENANCE

Maintenance Management Techniques for Tower Cranes

Maintenance of equipment, such as tower cranes, involves various management techniques. Two primary approaches are "Breakdown Maintenance" and "Planned Preventive Maintenance." Breakdown Maintenance entails performing maintenance only after a fault or failure occurs. However, for tower cranes, this approach is unsuitable because any failure poses an immediate safety risk. Therefore, the best practice for tower crane maintenance is "Planned Preventive Maintenance."

Planned Preventive Maintenance (PPM)

PPM involves routine inspections, replacing parts and consumables, and making necessary adjustments at predefined intervals to prevent equipment deterioration or failure. For tower cranes, this approach is crucial as it mitigates risks associated with equipment failure. Maintenance of tower cranes should be treated with the same importance as any other business activity because inadequate maintenance can lead to severe financial and safety consequences.

Effective Management Structure

An effective management structure is essential to ensure everyone involved in maintenance activities understands their responsibilities and is properly briefed on their duties. Systems must be in place for effective feedback and monitoring of maintenance data. Maintenance activities for tower cranes should follow the intervals specified in the manufacturer's maintenance manual. However, site-specific conditions may require more frequent maintenance.

Responsibilities

Once a tower crane is erected on-site, the user must ensure it is adequately maintained. Although the maintenance task is often delegated to the crane owner, the user retains overall responsibility. Clear lines of responsibility should be established from the Board level downwards. Those appointed to handle maintenance must possess sufficient knowledge and experience to manage risks effectively.

Preventive Maintenance Schedule

Each tower crane should have a documented preventive maintenance schedule targeting parts where failure or deterioration could lead to safety risks. The schedule should specify the frequency of inspections and tests for relevant parts, considering the manufacturer's instructions, the crane's age, and its usage history. If the crane owner lacks in-house engineering expertise, arrangements should be made to secure external professional advice. Guidelines should be established for when to seek this advice to ensure health and safety standards are met.

Record Keeping

For a preventive maintenance system to be effective, comprehensive records of daily checks, intermediate inspections, breakdown reports, maintenance work sheets, and thorough examination reports must be maintained. These records should be kept in an individual machine history file for the crane's entire lifespan. Systematic review of these records is crucial to ensure maintenance effectiveness, early detection of defects, and timely replacement of worn components. If the review shows maintenance is ineffective, the frequency and practices may need adjustments.

Training and Competence

Maintenance should only be performed by competent personnel with adequate training and information. Various general maintenance training courses and qualifications are available, including those provided by the National Construction College and the NVQ/SVQ scheme. Maintenance personnel must receive machine-specific training, traceable to the tower crane manufacturer, before undertaking any maintenance tasks.

Facilities and Equipment

Effective, efficient, and safe maintenance operations require adequate facilities and equipment. The sophistication of these facilities will depend on the scope of the maintenance tasks.

5.Conclussion

The study concludes that abrasion—specifically, the wear and tear of components such as bolts, nuts, and pins—is the most probable factor contributing to safety risks in tower crane operations. Additionally, it identifies the fracture of a wire rope during dismantling as having the highest impact on safety. Both these issues are significant maintenance management concerns, as highlighted by previous research.

To mitigate these risks, adopting a preventive maintenance strategy or conducting routine checks on tower crane parts and components is essential. This approach can significantly reduce the likelihood and impact of safety risks during the installation and dismantling of tower cranes. By focusing on regular inspections, timely replacement of worn parts, and maintaining detailed maintenance records, the overall safety and efficiency of tower crane operations can be greatly enhanced.

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