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Factors That Affect Safety of Tower Crane Installation/Dismantling in Construction Industry

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Abstract: ***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. These results may provide regulators as well as practitioners with insights for improving the safety of tower crane installation/dismantling.
Keywords: Installation & Dismantling, Practitioners, Safety, Stakeholders, Tower Cranes

I. INTRODUCTION

Tower cranes are used on construction sites as lifting equipment for their combination of height and lifting capacity. Tower crane accidents, however, are likely to be fatal because of the weight of the objects and the heights to which they are lifted. United States labour statistics recorded 632 crane-related construction worker deaths from 611 crane incidents and 17 multiple death incidents resulting in 38 deaths from 1992 to 2006**.** A crane safety analysis and recommendation report carried out in Singapore. Indicates that in 2008, there were 162 crane-related fatalities, injuries and dangerous occurrences, a 27% increase from 128 cases in 2007. While most of the cases involve less serious non-fatal injuries, crane accidents can ultimately result to huge and severe damage to physical properties and human lives.

Indoor posit that construction processes in Nigeria are characterized by unsafe practices leading to accident that leaves severe consequences on both the project and the workers. Accidents in building construction sites, whether minor or fatal could result to injuries, loss of resources, partial or permanent disability and death in case of fatalities.

In his analysis of types of accident that usually occur in construction sites, injury from the use of equipment ranked first among nine**.** Other types of accident examined.

Accidents frequently occur on Building construction sites, these accidents could be in the form of workers falling from heights, excavation accidents, the risk of falling debris or equipment's and so forth. Researches have shown that accidents and injuries in developing countries are generally high when compared to other European countries. Effective safety management is to make the environment safe, to make the job safe and to make workers safety conscious.

In recent years, many developed countries have considered safety as one of the important management issues of construction projects, especially, personal safety. He concludes that cranes are machines with high risk and should be operated with safety management and strong communication between crane operator and signalman. Factors that affect construction site safety due to the work of tower cranes have attracted only moderate attention; they are commonly addressed indirectly and partially within the broader treatment of site safety or of crane work in general**.** Literature addressing crane safety that explicitly suggests tower crane related risk factors or safety hazards is limited. Hence the need to critically examine safety issues regarding the installation/dismantling operation of tower cranes.

The objectives of this research are: i. to determine the probability of occurrence and degree of impact of safety risk factors during installation and dismantling of tower cranes in construction sites. ii.

To evaluate the safety risk factors based on established risk rating scales. Safety risk factors during the operation of tower cranes were not considered for this study only those associated with the process of installation and dismantling of tower cranes were considered.

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II. LITERATURE SURVEY

Idoro, G. I. Health and safety management efforts as correlates of performance in the Nigeria construction industry Journal of Civil Engineering and Management, Vol. 14, Number 4, pp 277–285, 2008

The consequences of building construction accidents are enormous and cannot be easily quantified, though inevitable but could be controlled to prevent minor or serious consequences to safety of workers [4]

Idoro, G.I. Effect of Mechanization on Occupational Health and Safety Performance in the Nigerian Construction Industry, Journal of Construction in Developing Countries, Vol. 16, Number 2, pp 27-45,

Idoro [10] asserted that although there is no reliable construction accident/incident data in Nigeria. However, a study of 40 contractors in 2006 revealed that accident and injury rates were high in the Nigerian construction industry and the best safety ratios were 2 accidents per 100 workers and 5 injuries per 100 workers.

Kadiri, Z.O., Nden, T., Avre, G.K., Oladipo, T.O., Edom, A., Samuel, P.O., & Ananso, G.N. Causes and Effects of Accidents on Construction Sites (A Case Study of Some Selected Construction Firms in Abuja F.C.T Nigeria), IOSR Journal of Mechanical and Civil Engineering, Vol.11, Number 5, pp 66-72, 2014

Kadiri, et. al [11] stated that as the growth of construction industry blossoms in Nigeria, this also causes an increase in competition of projects to execute between construction firms which are however achieved at the expense of the workers welfare and their safety Therefore identifying the various causes and effect of accidents on construction sites and proposing ways and means of reducing these accidents should be acknowledged. Erection/climbing/dismantling of tower cranes is a potentially hazardous process involving working at heights, awkward postures, lifting and aligning components of significant size and mass and installing temporary support systems.

Safework. Erection, climbing and dismantling tower cranes. Industry plant consultative committee, New South Wales, Australia, October 31, 2016

These are all often performed under significant time pressure due to the need for road closures, suitable daylight hours or short weather windows as the case maybe [12]

Occupational Safety and Health Administration (OSHA). Region 6 News Release: 12-2231- DAL, United States, November 20, 2012

The most dangerous process that can lead to fatalities at construction sites is the installation/dismantling of tower cranes; for instance, in 2012, the collapse of a tower crane during dismantling at the University of Texas, USA claimed the lives of two workers [13]

Ting, F. “The promotion strategy of occupational health and safety by government.” Annual meeting of Hong Kong Const

There have been five fatal accidents relating to tower crane use during 2002–2006 in Hong Kong, with three workers being killed in July 2007 alone. One such accident in July 2007 caused two fatalities and five serious injuries. The accident happened during the dismantling process, with workers on the tower crane as it crashed down [14]

Zhao, Q. Cause analysis of US crane-related accidents, MSc Dissertation, Graduate School of the University of Florida USA, 2011

Also in a related development, out of the 571 incident cases of crane related accidents that happened from 2000 – 2009 in the U.S as examined by [15]

Shin, I. J. Factors that affect safety of tower crane installation/dismantling in construction industry, Journal of Safety Science, Vol. 72, Number 2015, pp 379-390, 2015 41 cases which amounted to 7.18% occurred during assembly/disassembly. He further went ahead to say that 22 cases (23.40%) of the 94 cases that occurred from 2007-2009 resulted directly from the operations of assembly/disassembly. More recently, is an investigation of tower crane accidents that occurred in Korea from 2001-2011, it was reported that out of the 38 fatal accident cases involving tower cranes, 68.4% of the accidents resulted from the installation/dismantling operation [16]

Chi, S., Sangwon, H., Dae Y.K., & Yoonjung, S. Accident risk identification and its impact analyses for strategic construction safety management, Journal of Civil Engineering and Management, Vol. 21, Number 4, pp 524-538, 2015

Chi, et al. [17] opined that, risk identification and cautioning can improve the safety of workplaces. By organizing high recurrence risk factors to viably control accident occurrence and deal with the probability of lethal injuries on construction sites when an accident is unavoidable, enables/helps safety managers to comprehend the nature of construction accidents and plan for key risk mitigation Jannadi, O.A., & Almishari, S. Risk assessment in construction. Journal of Construction Engineering and Management, Vol. 129, Number 5, pp 492–500, 2003 However, [18] having concerted for the fact that assessment of risk is crucial for improving safety, went ahead to say that precise evaluation is not really necessary and that an estimated predicted level of risks will suffice for the safety managers to take necessary actions

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III. RESEARCH METHODOLOGY

The study looks at probability/likelihood of occurrence and impact of safety risk factors with respect to determining their frequency of occurrence and degree of impact respectively. This requires eliciting knowledge from practitioners who are directly involved in the process such as safety managers, equipment managers and team leaders of installation and dismantling workers. Hence, questionnaire survey was adopted. Population size for the research was unknown as no data is available on exact number of these practitioners. The sample size was determined from a table developed by that the minimum sample size for an unknown population for 95% confidence interval with 5% error level is approximately 34. A total of 57 questionnaires were generated and distributed in Chennai, Mumbai, and Delhi using purposive sampling technique. However, only 38(66.7%) questionnaires were analysed using descriptive statistics and results presented in tables.

A. Respondents Profile

This section presents the personal details of the respondents to include their nature of job, educational qualification and years of experience as presented in Table 2 indicates that all the categories of respondents are adequately represented having at least ≈ 30% representation each with safety managers having a higher representation of 36.8% and equipment managers having the least representation of 28.9%. All the respondents had at least a post-secondary education with 13(34.2%) of them having a bachelors and 6(15.8%) had MSc. Table 4.1 also shows that 34.2% of the respondents had between 0-5 years of experience. A cumulative of 65.8% of the respondents have at least 6years of experience working in tower crane environment and were therefore able to make correct and valid judgement.

Table 1: Respondents profile

Items	Frequency (No	Percentage (%)
Job Description		
Safety managers	14	36.8
Equipment managers	11	28.9
Installation and dismantling workers	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

B. Probability Of Occurrence For Safety Risk Factor

The probability of occurrence for each safety risk factor were scored by the respondents based on a five-point Likert scale. Mean values were determined, and standard deviation also determined to help rank the factors that have the same mean value as shown in Table 1 presents the assessment of the probability of occurrence of each factor which shows that the most probable factor is "Abrasion (wear and tear of components such as bolts, nuts or pins)" with a mean value of 3.63 and the least probable factor is "Incompatibility of components" with a mean value of 2.16. However, the first six (6) factors as seen in Table 2 had mean values ≥ 3.0 which means these factors have a possibility of occurring and may recur occasionally. The factors from 8th position to 21st had mean values ≥ 2.0 which means these factors are unlikely to recur but, have the possibility of occurring. We can conclusively say that these results implies that all the identified factors have the possibility of occurring on our construction sites.

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Researchers that previously looked at safety issues associated with tower crane installation and dismantling concluded that failure to follow work procedure is the most likely factor that can result to accidents on construction sites as stated by [13, 16]. However, the results presented in Table 2 proved otherwise by ranking "not following work procedure in manuals" as 12th position with a mean value of 2.89. This could imply that there have been an increased awareness and recognition of safety issues during installation and dismantling of tower cranes over the years which has made the users more safety conscious by implementing work procedures as stated in the manuals.

The most probable factor being "abrasion (wear and tear of components such as bolts, nuts, or pins)" has affirmed previous research finding that maintenance management is a highly affecting factor on safety when using tower cranes as stated by [9]. This implies that this factor yet plays a great influence on safety during installation and dismantling and/or during operation.

It is also interesting to note that operator proficiency or experience of the tower crane operator which has been widely accepted as the major safety determinant on site as cited by [1, 9, 22] was ranked 4th with a mean value of 3.18. This implies that although it remains a probable factor according to this study however, it has a greater influence on safety during the operation of tower crane. Another likely reason for this factor been ranked 4th could be that operators had gained experience over the years thereby reducing its influence on safety as tower cranes are now widely used and becoming a culture in every construction environment. Incompatibility of components ranked the least amongst all other factors assessed which implies that tower crane manufacturers have continuously improved on the compatibility of their tower crane components. More efforts is still required to completely eliminate this factor as it is still a probable factor although not recurring frequently.

Table 2: Probability of occurrence

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 cranes 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/dismantling 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	3	1	7	1	0	3	11	2.89	1.03	12t

	tower crane installation and dismantling.		3		5		8	0			h
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	Workers 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

C. Degree Of Impact For Safety Risk Factors

The impact of each factor were assessed using a five point Likert scale so as to establish their various levels of severity/degree of impact if they eventually occur on construction sites. The mean values were then calculated as shown in Table 3. fracture of a wire rope during dismantling had the highest degree of impact with a mean value of 4.63 which implies that the resultant effect of this safety risk factor if it occur is fatality, major injury/injuries, permanent impairment, critical process loss and critical property damage. The factor "workers (erectors, dismantlers) are leaving the work often due to hard working condition" had the lowest degree of impact with a mean value of 2.34 which therefore implies that it's resultant effect if it occur can only lead to minor injury. All the factors however had degree of impact that range from minor injury to fatality as shown in Table 4. There is a need to pay serious attention on the first six factors as they have mean values ≥ 4.0 which means if they occur, their resultant impact would lead to fatality on site.

Overloading tower cranes with objects exceeding its load limit is the 20th probable factor to occur on site as seen from Table 3. However, results for degree of impact in Table 4. Showed that it has a high degree of impact if its accident does happen on site as it was ranked 3rd position amongst other factors with a mean value of 4.18. The latter is in line with previous findings that exceeding tower crane load limit results to accident on site that could be very fatal involving multiple injuries in most cases. From a careful observation of this factor, one would notice a sharp distinction between its probability of occurrence and degree of impact. The reason for this could be linked to the

previous assertion that there has been a significant improvement in the level of safety awareness on site as a result of continuous research on safety challenges associated with tower crane working environment thereby, reducing the probability of occurrence which is a function of the probability of occurrence and the degree of impact. The result of this was then measured against a standard risk rating developed by [23] so as to come up with their risk levels as shown in Table 4.

Σα (probability risk score), Σβ (degree of impact risk score), ΣRS (combined risk score), N (population), RSIS (relative significance index score).

From Table 5, fracture of a wire rope during dismantling had the highest RSIS of 15.6 and implies a high risk factor which requires a high level of control put in place to forestall danger and make the working environment safer. The factors ranked from 2nd to 15th as shown in Table 5 had RSIS of 13.2 - 9.0 respectively, and as such implies that they are moderate risk factors that is acceptable but, requires suitable controls to maintain a safe working environment. Those ranked from 16th to 21st had RSIS of 7.9 – 6.4 respectively, which implies low risk factors that are acceptable with no further action required. The factor "workers (erectors, dismantler) are leaving the work often due to hard working condition" had the lowest RSIS of 6.4 and does not really pose any treat to safety.

This could be attributed to the high rate of unemployment in the country as reported by [24] thereby making the assertion in the factor false because, those who managed to be gainfully employed instead of leaving would rather do everything possible to keep their jobs so as to continue sustaining themselves. The fear that losing their job might make them become unemployed for the rest of their lives makes people.

Table 3: Degree of impact

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	Workers 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

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Table 4: Safety risk evaluation

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 cranes 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	Workers 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

Stick to the ones they have irrespective of the working condition. It is widely recognised that poor maintenance culture is lacking in both private and public sectors in Nigeria as stated by [25]. This could therefore be the reason why "fracture of a wire rope during dismantling" closely followed by "Abrasion (wear and tear of components such as bolts, nuts or pins) had high RSIS of 15.6 and 13.2 respectively. Routine maintenance of the tower cranes could help to minimize the risk level.

D. Safety Risk Factors During Installation And Dismantling Of Tower Cranes

Various factors affecting safety during installation and dismantling operation of tower cranes on construction sites are rarely reported nor documented for use as contractors are simply making maximum profit. Erection, dismantling and operations failure to follow a list of safety risk factors as shown in Table 5.

Table 5: Safety risk factors, [Reference 21]

S/No	Safety risk factors during installation and dismantling
1	Insufficient number of workers to perform the work correctly and safely.
2	Workers (erector, dismantler) are leaving the work often due to hard working condition).
3	Time constraints requested from employer/principal contractor.
4	Trying to finish the work earlier than the time required for safe work.
5	Frequently omitting required safety procedures or rules for various reasons.
6	Lack of workers competence.
7	Instruction and supervision at construction sites are insufficient.
8	Contractors do not recognize the need to ensure the safety tower crane installation/dismantling.
9	Unreasonable sites condition (working space, ground conditions and restrictions).
10	Deterioration of tower cranes part (components).
11	Workers attitude (installation/dismantling workers).
12	Overloading with objects exceeding the tower crane load limit.
13	Inexperienced tower crane operators.
14	Not following work procedures in manuals for the installation/climbing/dismantling of tower cranes.
15	Malfunction of a tower crane.
16	Buckling of a telescopic cage.
17	Fracture of a wire rope during dismantling.
18	Failure of working platforms.
19	Incompatibility of components.
20	Falling items.
21	Abrasion (wear and tear of components such as bolts, nuts, or pins.

IV. CONCLUSION

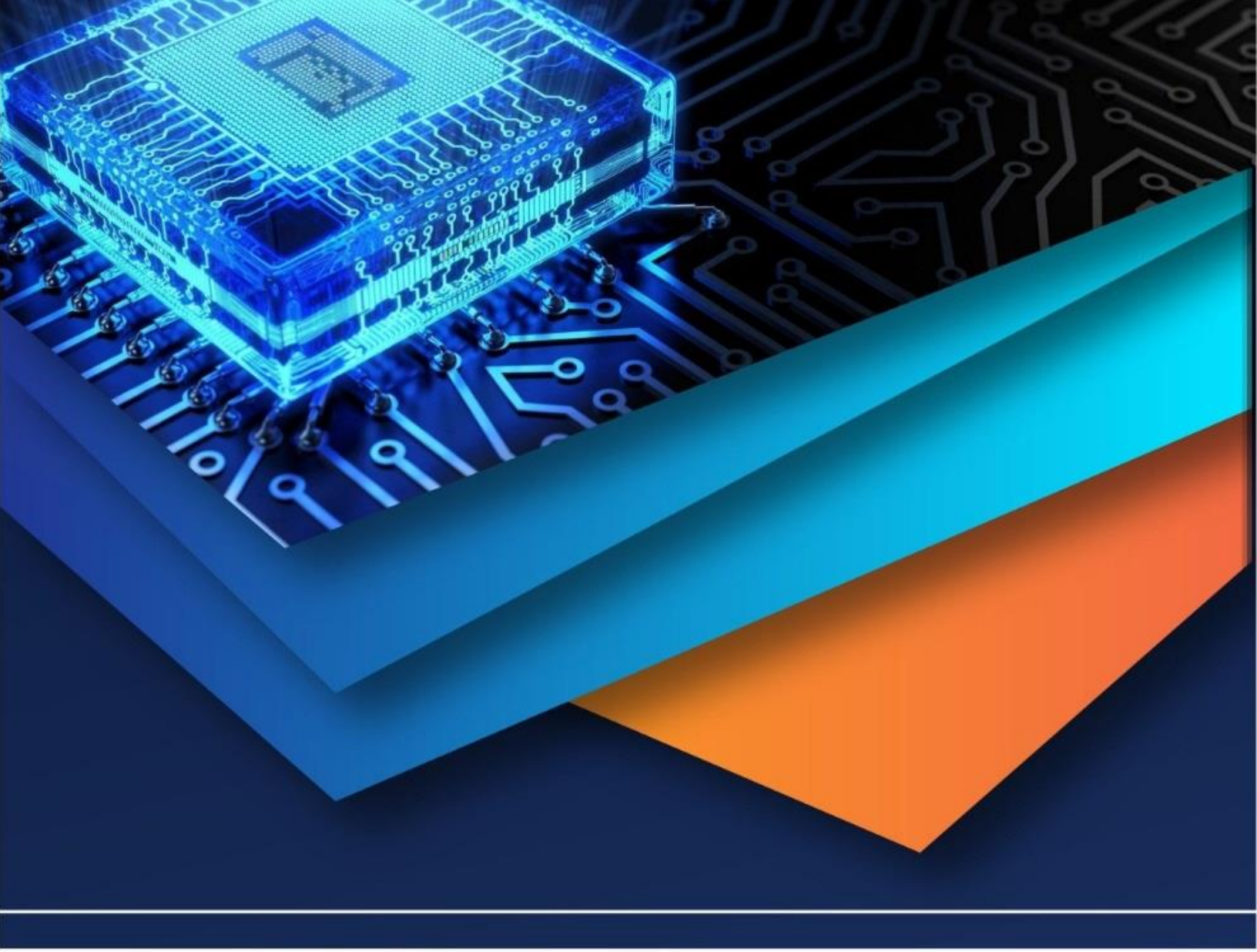
The study concludes that abrasion (wear and tear of components such as bolts, nuts, or pins) was the most probable factor and fracture of a wire rope during dismantling had the highest degree of impact. In evaluating the safety risk factors, "fracture of a wire rope during dismantling and abrasion (wear and tear of components such as bolts, nuts, or pins) which could both be seen as a maintenance management issue as looked at by previous research is a highly affecting factor on safety during installation and dismantling. Adoption of a preventive maintenance strategy or routine check on the tower crane parts and components could help minimize the probability of occurrence and impact of the safety risk factors on site during installation and dismantling of tower cranes.

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