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EVALUATING SAFETY RISKS IN TOWER CRANE ERECTION AND DISMANTLING IN VIETNAM

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Abstract: Accidents during the erection and dismantling of tower cranes can be fatal. This study aims to evaluate the causes of safety risks that arise during these processes in Vietnam based on the perceptions of construction project participants, including managers, erection and dismantling workers, and tower crane-related workers. A questionnaire using a five-point Likert scale was developed and distributed to 78 valid tower crane-related practitioners. All three groups identified "pressure of time from the principal contractor, employer, or investor" as the most common cause of safety risk and "breaking wire rope during installation and dismantling" as the most severe. Managers and erection and dismantling workers ranked "pressure of time from the principal contractor, employer, or investor" as the highest safety risk while tower crane-related workers identified "pins, nuts, or bolts of tower cranes having wear and tear" as the most critical safety risk. Manager-related causes were found to be the most significant, particularly "pressure of time from the principal contractor, employer, or investor" and "construction sites with deficient safety instructions and supervisions". Worker- and equipment-related causes were considered less critical.

Keywords: Erection, dismantling, tower crane, safety risk causes, construction industry.

Introduction

The construction industry has the highest number of accidents globally, often resulting in fatalities, severe injuries, and other serious consequences (Tam & Fung, 2011; Soltanmohammadlou *et al*., 2019; William *et al*., 2022). For instance, in the United Kingdom , the construction sector accounts for about 59,000 non-fatal work-related injuries from 2019 to 2022 and 66 fatal injuries to workers from 2017 to 2022 (Health and Safety Executive, 2022). In the United States, construction is one of two fields that have the highest death rate, with 1,056 deaths in 2022 (Department of Labor Grants, 2022). Similarly, Vietnam's construction sector has a high incidence of accidents and fatalities, accounting for 12.23% of all workplace accidents and 12.26% of total work-related deaths in 2022 (Vietnam Ministry of Labour-Invalids and Social Affairs, 2023).

Tower cranes are widely used in construction projects, especially for high-rise buildings, factories, or commercial centres. Their numbers are expected to increase over time due to their essential role in lifting and transporting building materials (Shapira & Lyachin, 2009; Shin, 2015; Ngo, 2023). However, tower cranes contribute significantly to serious accidents, often leading to severe injuries and fatalities (Shapira *et al*., 2012).

These cranes pose risks not only to construction workers, but also to machinery, equipment, nearby structures, and pedestrians (Tam & Fung, 2011; Marquez *et al*., 2014). For example, in Australia, tower crane accidents resulted in 47 fatalities between 2003 and 2015, along with approximately 240 serious injuries annually (Safe Work Australia, 2016; 2019). In South Korea, 38 tower crane-related accidents occurred between 2001 and 2011, accounting for approximately 7.2% of all lifting equipment accidents (Shin, 2015). Vietnam has also experienced tower crane-related accidents, including one in May 2020 that resulted in three fatalities and three serious injuries.

The erection and dismantling of tower cranes are particularly hazardous, contributing to a significant number of construction site accidents and fatalities (Shin, 2015). In Korea, 68.4% of all fatal tower crane-related accidents from 2001 to 2011 occurred during erection and dismantling (Shin, 2015). Similarly, in Hong Kong, a dismantling-related accident in July 2007 resulted in two deaths and five serious injuries (Li e*t al*., 2012). Vietnam has also witnessed such incidents, including a February 2020 accident that killed three workers and seriously injured two others, as well as another accident in July 2023 that caused three serious injuries. Globally, few studies have examined the causes of safety risks associated with tower cranes, with most research focusing only on specific aspects of their operation. Therefore, evaluating the safety risks associated with tower crane erection and dismantling in Vietnam, as perceived by different construction project participants—including managers, erection and dismantling workers, and tower crane-related workers—is essential.

This study aims to achieve several objectives. First, it identifies the most frequent causes of safety risks during the erection and dismantling of tower cranes in Vietnam. Second, it determines the most severe safety risks involved in these processes. Third, it evaluates the significance of safety risk factors by calculating a relative significance index score. Fourth, it categorises safety risk causes based on their frequency, degree of influence, and risk level, as perceived by different construction project participants. Finally, the study assesses the Spearman rank correlation coefficient between the perceptions of different groups.

Literature Review

Numerous studies have examined the safety risk associated with cranes at construction sites (Shapira & Simcha, 2009; Tomakov *et al*., 2018; Im & Park, 2020; Lingard *et al*., 2021; Sadeghi *et al*., 2021). However, relatively few have specifically investigated the safety risks of tower cranes at construction sites. Shapira and Lyachin (2009) identified and analysed the causes of safety risks associated with tower cranes at construction sites in Israel. They highlighted 21 safety risk causes during the operation of a tower crane, categorised into four main groups: Project conditions, safety management, human factors, and environmental conditions. They used the analytic hierarchy process technique to evaluate the weight of 21 safety risks caused in tower crane operations. Additionally, Shapira *et al.* (2012) developed an integrated model comprising four modules to quantify safety risk causes during tower crane operations at construction sites. Zhou *et al.* (2018), meanwhile, identified safety risk causes in tower crane operations in China using the qualitative AcciMap technique. Tam and Fung (2011) examined the safety risks associated with tower crane operations in Hong Kong through interviews.

Despite these studies, most have focused on crane operations rather than the specific risks involved in tower crane erection and dismantling. Li *et al.* (2012) introduced a safety training method for dismantling tower cranes on construction sites, demonstrating that the proposed method was more effective than previous approaches. Shin (2015) investigated the causes of safety risks in the erection and dismantling of tower cranes in Korea by reviewing 38 accidents from 2001 to 2011.

The study identified five major safety risk factors, with human errors being the most significant cause of accidents. These five major causes included: (i) Poor quality of materials required for erection and dismantling; (ii) inadequate knowledge and skills of erectors and dismantlers; (iii) deterioration in the quality of tower crane components during storage; (iv) insufficient site supervision; and (v) poor working conditions, including adverse weather, limited space, and time constraints. Similarly, Salihu *et al*. (2020) evaluated safety risk causes in the erection and dismantling of tower cranes on construction sites in Nigeria. By interviewing 57 individuals involved in tower crane erection and dismantling, the study assessed the frequency and influence of 21 safety risk causes and identified the most significant ones. Ngo

(2023) also identified 21 safety risk causes affecting tower crane erection and dismantling in Vietnam.

Methods

The research framework is shown in Figure 1. 21 safety risk causes were identified in ta previous study (Ngo, 2023) and are listed in Table 1. These causes are categorised into three groups: Managers (five causes), workers (nine causes), and equipment (seven causes). A structured questionnaire was developed to evaluate the frequency of occurrence, degree of influence (severity) and importance of the identified safety risk causes among other participants by using a five-point Likert scale. Frequency of occurrence was ranked from 1 (improbable), to 2 (unlikely), 3 (possible), 4 (probable), and 5 (almost certain). The degree of influence of causes was ranked from 1 (negligible), to 2 (minor injury), 3 (major injury), 4 (fatality), and 5 (multiple fatalities). A total of 120 questionnaires were istributed to managers, erection and dismantling workers, and tower crane-related workers. Data were analysed based on frequency, severity, and importance indices. Agreement on the ranking of safety risk causes between different groups was also examined. According to Louanglath (2014), a minimum sample size of 34 is required for a 95% confidence interval with a 5% margin of error.

The safety risk level of each cause was assessed by calculating their Relative Significant Index Score (RSIS). The RSIS can be calculated by the following equation:

$$\text{RSIS} = \alpha_{mean} \cdot \beta_{mean} = \frac{\sum\alpha}{N} \cdot \frac{\sum\beta}{N} \quad (1)$$

where α_{mean} is the likelihood mean value, $\sum\alpha$ is the sum of likelihood risk score, β_{mean} is the degree of influence mean value, $\sum\beta$ is the sum of degree of influence risk score, and N is the number of respondents per case. Equation (1) allows the determination of the relative significance of each risk cause by considering its likelihood and severity.

The value of RSIS was then compared against a table of standard risk values proposed by the Construction Plant Hire Association (CPA, 2011). Data analysis was conducted using Microsoft Excel. Spearman's rank correlation,

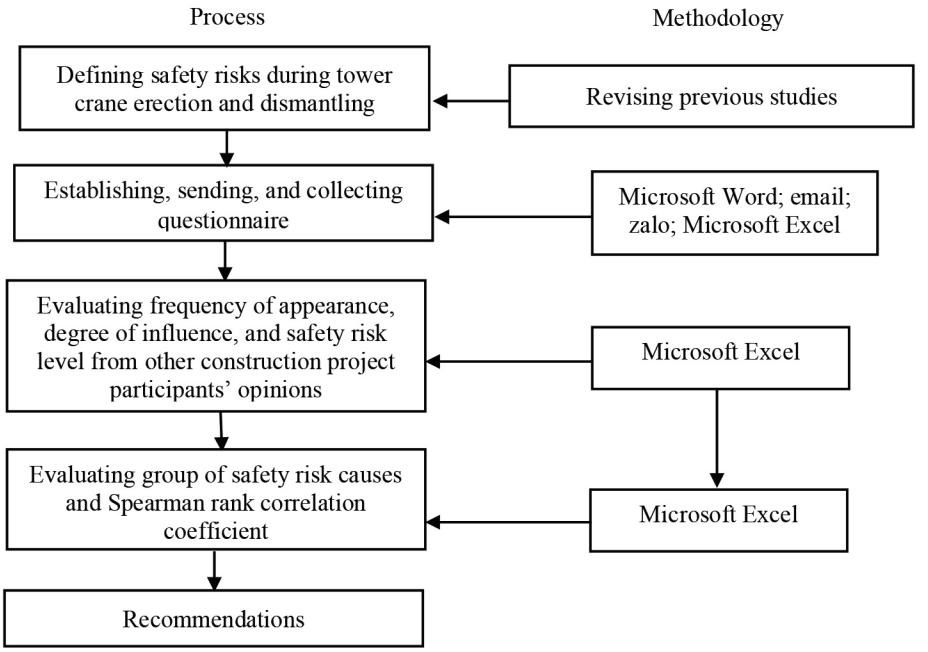

Figure 1: Research framework

a non-parametric test was used to measure agreement between groups. This method does not require assumptions of normality or homogeneity of variance and is effective for datasets with outliers. In this study, Spearman's rank correlation coefficient is used to show the degree of agreement between the different parties. Concretely, it is used to measure and compare the association between the rankings of two parties for a single safety risk cause while ignoring the ranking of the third party. The correlation coefficient varies between -1 and +1, where -1 refers to an absolute negative relationship (disagreement) while +1 refers to an absolute positive relationship (agreement). According to Assaf and Al-Hejji (2006), Spearman's rank correlation is as folows:

$$r = 1-[(6\sum d2)/(n3-n)] \quad (2)$$

where r is the Spearman's rank correlation coefficient between two parties, n is the number of pairs of rank, and d is the difference between ranks assigned to variables for each cause.

Table 1: List of safety risk causes categorised into three groups (Ngo, 2023)

No.	Safety Risk Causes
	Managers
1	Shortage of workers to warrant working correctly and safely
2	Contractors do not take care to ensure the safety during erection and dismantling
3	Pressure of time from the principal contractor, employer, or investor
4	Poor conditions of construction sites (i.e., working space, ground, environment, and other restrictions)
5	Deficient safety instruction and supervision of construction sites
	Workers
6	Tower crane-related workers do not work due to uncomfortable working conditions
7	Not following safety procedures or rules required during erection and dismantling
8	Workers with insufficient competence
9	Tower crane operators with insufficient experiences
10	Attempting to complete the work earlier than the necessary time
11	Not following procedures in manuals when erecting and dismantling tower cranes
12	Falling items
13	Unsuitable character of erection and dismantling workers
14	Tower crane with overload
	Equipment
15	Tower crane failure
16	Warping of a telescopic cage
17	Broken wire rope during erecting and dismantling
18	Insufficiency of working platforms
19	Details of tower crane have not synchronous
20	Pins, nuts, or bolts of tower cranes have wear and tear
21	Quality decline of components of tower cranes

Research Findings and Results

General Characteristics of Respondents

A total of 78 valid responses were collected, resulting in a response rate of 65%. Table 2 presents the demographic characteristics of the respondents, including their job roles, educational qualifications, and years of experience. Erection and dismantling workers comprised the largest proportion of respondents (52.6%) while managers, including safety managers, equipment managers, and project managers, represented the smallest group (21.8%). All respondents had at least a post-secondary education. Among them, secondary school graduates accounted for the highest proportion (64.1%), whereas those with an MSc qualification had the lowest representation (9.0%).

Regarding work experience, 56.4% of respondents had between 11 and 20 years of experience with tower cranes on construction sites. Specifically, 29.5% had 11 to 15 years of experience while 26.9% had 16 to 20 years. Additionally, 6.4% had less than five years of experience, 20.5% had six to 10 years, and 16.7% had over 20 years of experience.

Ranking Safety Risk Causes by Parties

The ranking of safety risk causes based on frequency of occurrence, degree of severity, and overall safety risk level as assessed by managers, erection and dismantling workers, and tower crane-related workers is presented

Table 2: Respondents' profile

No.	Item	Number	Percentage (%)
	Job description		
1	Managers (Safety managers; equipment, managers, and project managers)	17	21.8
2	Erection and dismantling workers	41	52.6
3	Tower crane-related workers	20	25.6
	Total	**78**	**100**
	Educational qualification		
1	High school	7	9.0
2	Secondary graduation	50	64.1
3	Bachelors	12	15.4
4	MSc	9	11.5
	Total	**78**	**100**
	Years of experience		
1	0-5	5	6.4
2	6-10	16	20.5
3	11-15	23	29.5
4	16-20	21	26.9
5	Over 20	13	16.7
	Total	**78**	**100**

in Tables 3 to 5. As shown in Tables 3 to 5, all three groups identified "pressure of time from the principal contractor, employer, or investor" as the most common cause of safety risk. Additionally, "broken wire rope during erecting and dismantling" was recognised as the most severe safety risk.

Managers and erection and dismantling workers ranked "pressure of time from the principal contractor, employer, or investor" as the highest safety risk overall. However, tower crane-related workers identified "pins, nuts, or bolts of tower cranes having wear and tear" as the highest safety risk. Table 6 indicates that manager-related causes are the most significant contributors to safety risks while worker- and equipment-related causes are comparatively less critical.

Table 3 presents managers' assessments of safety risk causes. According to managers, "pressure of time from the principal contractor, employer, or investor" was the most common cause of safety risk, with a mean value of 3.88, whereas "falling items" was ranked the least likely cause, with a mean value of 1.82. "Broken wire rope during erecting and dismantling" was identified as having the highest severity, with a mean value of 3.41 while "not following safety procedures or rules required during erection and dismantling" had the lowest degree of impact, with a mean value of 2.06.

As shown in Table 3, "pressure of time from the principal contractor, employer, or investor" had the highest Risk Severity Impact Score (RSIS) of 10.28, whereas "not following safety procedures or rules required during erection and dismantling" had the lowest RSIS of 4.24. Eight safety risk causes had a high RSIS (> 8.0), indicating that they are of moderate concern and require appropriate control measures during tower crane erection and dismantling to enhance safety. Causes ranked from 9th to 21st had RSIS values ranging from 7.89 to 4.24, classifying them as low-risk and generally acceptable without additional control measures. Among the three groups of safety risk causes, manager-related causes had the highest RSIS of 8.16.

Table 3: Safety risk causes according to managers

No.	Causes	Frequency of Occurrence			Degree of Severity		Safety Risk Level		
		Mean	Std. Dev.	Rank	Mean	Rank	RSIS	Rank	Risk Level
	Managers	**3.09**	**0.96**		**2.66**		**8.16**		**M**
1	Shortage of workers to warrant working correctly and safely	2.77	0.97	6th	3.12	5th	8.62	6th	M
2	Contractors do not take care to ensure the safety during erection and dismantling	2.73	1.05	7th	2.12	20th	5.73	17th	L
3	Pressure of time from the principal contractor, employer, or investor	3.88	0.86	1st	2.65	11th	10.28	1st	M
4	Poor conditions of construction sites (i.e., working space, ground, environment, and other restrictions)	3.35	0.79	2nd	2.35	17th	7.89	9th	L

5	Deficient safety instruction and supervision of construction sites	2.72	1.11	8th	3.06	8th	8.28	8th	M
	Workers	**2.51**	**0.92**		**2.81**		**7.00**		**L**
6	Tower crane-related workers do not work due to uncomfortable working conditions	2.71	0.59	9th	3.30	3rd	8.91	4th	M
7	Not following safety procedures or rules required during erecting and dismantling	2.06	0.90	17th	2.06	21st	4.24	21st	L
8	Workers with insufficient competence	2.59	0.94	13th	2.65	11th	6.85	12th	L
9	Tower crane operators with insufficient experiences	3.24	1.20	4th	2.59	14th	8.38	7th	M
10	Attempting to complete the work earlier than the necessary time	3.30	1.21	3rd	3.11	6th	10.27	2nd	M
11	Not following procedures in manuals when erecting and dismantling tower cranes	2.65	0.86	12th	2.30	18th	6.03	15th	L
12	Falling items	1.82	0.81	21st	3.36	2nd	6.11	13th	L
13	Unsuitable character of erection and dismantling workers	1.89	0.78	20th	2.77	10th	5.20	18th	L
14	Tower crane with overload	2.24	1.03	15th	3.11	6th	6.97	11th	L
	Equipment	**2.46**	**0.87**		**2.77**		**6.85**		**L**
15	Tower crane failure	2.70	0.59	10th	3.29	4th	8.90	5th	M
16	Warping of a telescopic cage	2.53	0.80	14th	2.41	16th	6.10	14th	L
17	Broken wire rope during erecting and dismantling	2.23	0.97	16th	3.41	1st	7.63	10th	L
18	Insufficiency of working platforms	1.94	0.66	19th	2.64	12th	5.14	19th	L
19	Details of tower crane have not synchronous	1.93	0.90	18th	2.47	15th	4.80	20th	L
20	Pins, nuts, or bolts of tower cranes have wear and tear	3.20	1.24	5th	2.94	9th	9.34	3rd	M
21	Quality decline of components of tower cranes	2.69	0.92	11th	2.24	19th	6.05	16th	L

M: Moderate; L: Low

Erection and dismantling workers' opinions are presented in Table 4. The results indicate that "pressure of time from the principal contractor, employer, or investor" is the most common cause of safety risk, with a mean value of 3.56 while "details of tower crane have not synchronous" is the least common, with a mean value of 2.24. The cause with the highest degree of impact is "broken wire rope during erecting and dismantling", with a mean value of 3.81, whereas "details of tower crane have not synchronous" has the lowest degree of influence, with a mean value of 2.29. Table 4 also shows that "pressure of time from the principal contractor, employer, or investor" has the highest RSIS at 10.94 while "details of tower crane have not synchronous" has the lowest RSIS at 5.14. Additionally, 17 causes exhibit a high RSIS (> 8.0), whereas the causes ranked 18th to 21st have RSIS values ranging from 7.66 to 5.14. Among the three groups of causes, worker-related factors have the highest RSIS, at 9.61.

Table 4: Safety risk causes according to erection and dismantling workers

No.	Causes	Frequency of Occurrence			Degree of Severity		Safety Risk Level		
		Mean	Std. Dev.	Rank	Mean	Rank	RSIS	Rank	Risk Level
	Managers	**2.99**	**1.16**		**3.18**		**9.46**		**M**
1	Shortage of workers to warrant working correctly and safely	2.73	1.23	14th	3.46	8th	9.46	11th	M
2	Contractors do not take care to ensure the safety during erection and dismantling	2.83	1.07	11th	2.68	19th	7.59	19th	L
3	Pressure of time from the principal contractor, employer, or investor	3.56	1.07	1st	3.07	14th	10.94	1st	M
4	Poor conditions of construction sites (i.e., working space, ground, environment, and other restrictions)	3.00	1.25	5th	3.00	16th	9.00	13th	M
5	Deficient safety instruction and supervision of construction sites	2.81	1.19	12th	3.68	3rd	10.33	3rd	M
	Workers	**2.46**	**1.18**		**3.43**		**9.61**		**M**
6	Tower crane-related workers do not work due to uncomfortable working conditions	2.56	1.23	18th	3.51	6th	8.99	14th	M
7	Not following safety procedures or rules required during erection and dismantling	2.88	1.05	9th	3.44	9th	9.90	6th	M

8	Workers with insufficient competence	2.66	1.13	15th	3.73	2nd	9.92	5th	M
9	Tower crane operators with insufficient experiences	3.02	1.01	3rd	3.20	11th	9.66	7th	M
10	Attempting to complete the work earlier than the necessary time	2.93	1.10	7th	3.25	10th	9.49	10th	M
11	Not following procedures in manuals when erecting and dismantling tower cranes	2.86	1.26	10th	3.02	15th	8.63	16th	M
12	Falling items	2.76	1.22	13th	3.66	4th	10.08	4th	M
13	Unsuitable character of erection and dismantling workers	2.61	1.22	17th	3.50	7th	9.17	12th	M
14	Tower crane with overload	2.48	1.42	6th	3.59	5th	10.67	2nd	M
	Equipment	**2.69**	**1.16**		**2.96**		**8.00**		**L**
15	Tower crane failure	3.01	1.15	4th	3.19	12th	9.65	8th	M
16	Warping of a telescopic cage	2.65	1.09	16th	2.88	17th	7.66	18th	L
17	Broken wire rope during erecting and dismantling	2.51	1.14	19th	3.81	1st	9.57	9th	M
18	Insufficiency of working platforms	2.46	1.05	20th	2.81	18th	6.91	20th	L
19	Details of tower crane have not synchronous	2.24	1.09	21st	2.29	21st	5.14	21st	L
20	Pins, nuts, or bolts of tower cranes have wear and tear	2.90	1.24	8th	3.10	13th	8.98	15th	M
21	Quality decline of components of tower cranes	3.05	1.36	2nd	2.63	20th	8.03	17th	M

M: Moderate; L: Low

Tower crane-related workers' opinions are presented in Table 5. The results indicate that "pressure of time from the principal contractor, employer, or investor" is the most common cause of safety risk, with a mean value of 3.45 while "details of tower crane have not synchronous" is the least common, with a mean value of 2.05. The cause with the highest degree of impact is "broken wire rope during erecting and dismantling", with a mean value of 3.80, whereas "contractors do not take care to ensure safety during erection and dismantling" has the lowest degree of influence, with a mean value of 1.75. Table 5 also shows that "pins, nuts, or bolts of tower cranes have wear and tear" has the highest RSIS at 11.06 while "details of tower crane have not synchronous" has the lowest RSIS at 3.69. Additionally, 12 causes exhibit a high RSIS (> 8.0), whereas the causes ranked 13th to 21st have RSIS values ranging from 7.72 to 3.69. Among the three groups of causes, worker-related factors have the highest RSIS, at 8.15.

Table 5: Safety risk causes according the tower crane-related workers

No.	Causes	Frequency of Occurrence			Degree of Severity		Safety Risk Level		
		Mean	Std. Dev.	Rank	Mean	Rank	RSIS	Rank	Risk Level
	Managers	**2.90**	**1.18**		**2.66**		**7.69**		**M**
1	Shortage of workers to warrant working correctly and safely	2.35	1.27	18th	2.65	17th	6.23	19th	L
2	Contractors do not take care to ensure the safety during erection and dismantling	2.90	1.25	5th	1.75	21st	5.08	20th	L
3	Pressure of time from the principal contractor, employer, or investor	3.45	1.32	1st	2.81	13th	9.66	2nd	M
4	Poor conditions of construction sites (i.e., working space, ground, environment, and other restrictions)	3.25	0.97	3rd	2.75	16th	8.94	4th	M
5	Deficient safety instruction and supervision of construction sites	2.55	1.10	13th	3.34	5th	8.54	9th	M
	Workers	**2.59**	**1.21**		**3.15**		**8.15**		**M**
6	Tower crane-related workers do not work due to uncomfortable working conditions	2.45	1.05	14th	3.15	9th	7.72	13th	L
7	Not following safety procedures or rules required during erection and dismantling	2.59	1.39	12th	3.10	10th	8.06	12th	M
8	Workers with insufficient competence	2.25	1.29	19th	3.20	7th	7.20	15th	L
9	Tower crane operators with insufficient experiences	2.89	0.97	6th	3.00	12th	8.70	6th	M
10	Attempting to complete the work earlier than the necessary time	2.80	1.00	7th	2.40	18th	8.68	7th	M
11	Not following procedures in manuals when erecting and dismantling tower cranes	2.70	1.22	9th	3.02	11th	6.48	17th	L
12	Falling items	2.40	1.27	17th	3.65	2nd	8.76	5th	M
13	Unsuitable character of erection and dismantling workers	2.43	1.32	16th	3.50	3rd	8.56	8th	M

14	Tower crane with overload	2.79	1.42	8th	3.30	6th	9.24	3rd	M
	Equipment	**2.60**	**1.08**		**2.84**		**7.43**		**L**
15	Tower crane failure	2.61	1.10	10th	3.19	8th	8.32	11th	M
16	Warping of a telescopic cage	2.60	1.05	11th	2.80	14th	7.28	14th	L
17	Broken wire rope during erecting and dismantling	2.20	0.95	20th	3.80	1st	8.36	10th	M
18	Insufficiency of working platforms	2.44	0.83	15th	2.79	15th	6.86	16th	L
19	Details of tower crane have not synchronous	2.05	0.94	21st	1.80	20th	3.69	21st	L
20	Pins, nuts, or bolts of tower cranes have wear and tear	3.30	1.26	2nd	3.35	4th	11.06	1st	M
21	Quality decline of components of tower cranes	3.00	1.41	4th	2.15	19th	6.45	18th	L

M: Moderate; L: Low

Table 6: Ranking safety risk causes by all parties (combined)

No.	Causes	Frequency of Occurrence		Degree of Severity		Safety Risk Level		
		Mean	Rank	Mean	Rank	RSIS	Rank	Risk Level
1	Manager-related causes	2.83	1st	2.83	3rd	8.44	1st	M
2	Worker-related causes	2.52	3rd	3.13	1st	8.25	2nd	M
3	Equipment-related causes	2.58	2nd	2.85	2nd	7.43	3rd	L

Importance Rank Correlation

The Spearman's rank correlation coefficient was applied to assess the level of agreement between two groups while excluding the ranking of the third group. As shown in Table 7, the correlation coefficients range from 0.529 to 0.614, indicating a moderate positive relationship. The strongest correlation is between erection and dismantling workers and tower crane-related workers (0.614) while the weakest is between managers and erection and dismantling workers (0.529). These findings suggest a relatively good agreement between the groups in ranking safety risk causes. The results are considered reliable due to the consistency in rankings among the groups.

Table 7: Spearman rank correlation coefficient

No.	Parties	Spearman Rank Correlation Coefficient	Significance Level
1	Managers and erection and dismantling workers	0.529	0.95
2	Managers and tower crane-related workers	0.545	0.95
3	Erection and dismantling workers and tower crane-related workers	0.614	0.95

Discussion

This study identified 21 causes and three cause groups of safety risks associated with the erection and dismantling of tower cranes at Vietnamese construction sites. It assessed these causes and groups based on frequency of occurrence, degree of influence, and safety risk level as perceived by managers, erection and dismantling workers, and tower crane-related workers. The participants' opinions were largely similar, with all groups identifying "pressure of time from the principal contractor, employer, or investor" as the most common cause and "broken wire rope during erection and dismantling" as the most severe cause. However, their assessments of the highest safety risk level differed. Managers and erection and dismantling workers identified "pressure of time from the principal contractor, employer, or investor" as the highest risk while tower crane-related workers considered "pins, nuts, or bolts of tower cranes having wear and tear" as the most critical risk factor. Additionally, manager-related causes were the most common and carried the highest safety risk level while worker-related causes were considered the most severe.

Previous studies on tower crane safety during erection and dismantling primarily focused on identifying individual risk factors without evaluating perceptions across different construction project participants. For example, Shin (2015) reviewed 38 tower crane accidents in South Korea between 2001 and 2011 while Salihu *et al*. (2020) and Ngo (2023) identified 21 safety risk causes in Nigeria and Vietnam, respectively. These studies assessed frequency of occurrence and degree of influence but did not compare risk perceptions among participant groups or examine groups of causes.

This study distributed questionnaires to companies of similar size within the same construction sector in Northern Vietnam. Future research should expand the sample size and geographic coverage to enhance reliability. Additionally, further studies should focus on each participant group separately to better understand their specific risk perceptions. This research highlighted differences in risk assessments between participant groups and cause groups, contributing to a more comprehensive understanding of tower crane safety risks.

Conclusions

This study evaluated safety risk causes during the erection and dismantling of tower cranes at construction sites in Vietnam based on the perceptions of managers, erection and dismantling workers, and tower crane-related workers. All three groups identified "pressure of time from the principal contractor, employer, or investor" as the most common cause and "broken wire rope during erection and dismantling" as the most severe. However, while managers and erection and dismantling workers ranked "pressure of time from the principal contractor, employer, or investor" as the highest safety risk, tower crane-related workers identified "pins, nuts, or bolts of tower cranes having wear and tear" as the greatest risk.

Among the three cause groups, manager-related causes were considered the most significant while worker- and equipment-related causes were ranked lower. The relatively strong agreement between participant groups in ranking safety risks suggests the reliability of the findings.

Future research should expand the sample size and geographical coverage to improve reliability. Additionally, further studies should examine each participant group separately. Another potential area for future research is the safety risks associated with operating tower cranes at construction sites in Vietnam.

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Conflict of Interest Statement

The authors declare that they have no conflict of interest.

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