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An Estimation of the Safety Risk Factors Encountered During Tower Crane Installation and Dismantling on Construction Sites in Vietnam

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Abstract: The construction field has an important and meaningful role in the economy of any nation, especially developing nations. However, construction is one of the most dangerous fields and has the highest rate of accidents, including deaths and disabling injuries in the world. The construction field uses many tower cranes, especiallyfor constructing multi-storey buildings, factories, or in urban areas, and requires an increasing number of tower cranes. Tower cranes certainly contribute to the high rate of construction injuries and fatalities, in which tower crane installation and dismantling take a high rate. Accidents during tower crane installation and dismantling can kill people (workers and citizens) as well as delays in construction schedules of project and/or damage to buildings and machines under construction. As a result, the cost of costruction projects can increase. In this paper, safety risk factors during tower crane installation and dismantling on construction sites in Vietnam are estimated by showing their likelihood of occurrence, degree of influence, and risk levels. A suitable-structured questionnaire was produced and sent to get data that had their likelihood of occurrence and degree of influence by applying a five-point Likert scale. The results showed that "Time constraints are requested by investor, principal contractor or employer" is the most likely factor with a mean value of 3.60 and "Break of a wire rope occurring on dismantling" has the highest degree of influence, with a mean value of 4.18. The result also showed that there are 15/21 factors with a moderate risk level that is acceptable but, requires suitable controls to maintain a safe working condition of tower crane installation and dismantling. The results of the paper may help managers as well as practicians with good understandings of how to advance the safety of tower crane installation and dismantling on construction sites in Vietnam.

Keywords: Tower crane, accident, installation, dismantling, construction safety, construction field

1. Introduction

Construction is one of the most dangerous fields, and the construction field has the highest rate of accidents including fatalities, disabling injuries and other serious damages around the world (Ahmed et. al., 2000; Fang, Song, & Huang, 1999; Koehn, Kothari, & Pan, 1995; Harper & Koehn, 1997; Sawacha, Naoum, & Fong, 1999; Tam & Fung, 2011; Farooqui, Arif, & Rafeeqi, 2008; Neitzel, Seixas, & Ren, 2001). In Vietnam, the construction field has many accidents and has a high rate of accidents including fatalities and disabling injuries with 15.6% total number of accidents and 16.5% total number of deaths in 2020 (Vietnam Ministry of Labour-Invalids and Social Affairs, 2020). The construction field uses many tower cranes, especially for constructing multi-storey buildings, factories, or in urban

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areas and requires an increasing number of tower cranes (Shin, 2015). Tower cranes are the really important machines, which have been used on most construction sites in the world and in Vietnam as well to transport materials. Tower cranes have heights of more than 200 ft, boom length of more than 250 ft, and load capacities of more than 22 tons (Neitzel, Seixas, & Ren, 2001) and tower cranes hoist and transport a variety of loads (Shapira & Lyachin, 2009). They displayed an average 36% of the total project procurement cost (Yeo & Ning, 2006). However, tower cranes absolutely cause a high number of injuries and deaths on construction sites (Neitzel, Seixas, & Ren, 2001; Shapiro & Shapiro, 2004; Skinner, et. al., 2006; Shapira, Simcha, & Goldenberg, 2012). For example, Tam & Fung (2011) showed that there were 12 accidents involving tower cranes from 1998 to 2005 in Hong Kong. There were 38 accidents involving tower cranes in Korea from 2001 to 2011 (Shin, 2015). According to the statistics from the Occupational Safety Health Administration (OSHA) (Kang & Miranda, 2004), there were 137 crane-related deaths from 1992 to 2001 in the United States. There were 47 deaths in incidents involving cranes from 2003 to 2015 in Australia (Safe Work Australia, 2016) and 240 crane-related serious injuries every year (Safe Work Australia, 2019). In England, cranes accounted for 17% of all construction-related deaths (Health and Safety Executive, 1978). Vietnam had some accidents involving tower crane. For example, in May 2020 an accident happened to a tower crane with three fatalities and three serious injuries.

Installation and dismantling of tower cranes has a high rate of accidents. The most dangerous works that can cause deaths at construction sites is the tower crane installation and dismantling (Shin, 2015; Li, Chan, & Skitmore, 2012). There were 68.4% of all fatal accidents during tower crane installation and dismantling from 2001 to 2011 in Korea (Shin, 2015). Erection and dismantling caused 10% to 12% of all crane fatalities in the United States (Smith & Corley, 2009). The accident happened while dismantling a process tower crane in Hong Kong in July 2007. This accident caused five serious injuries and two fatalities (Li, Chan, & Skitmore, 2012). In Vietnam in February 2020, there were three fatalities and two serious injuries in an accident that happened during a tower crane dismantling process.

Some factors that affect the safety of tower cranes on construction sites have some studies, but most of them only talk about the broader field of construction site safety or of crane-related work in general (Nunnally, 2000). In Vietnam, there are a few suggestions related risk factors or safety hazards of tower cranes (Shapira & Lyachin, 2009). Thus, safety issues regarding the operation of tower cranes on construction sites in Vietnam need to be evaluated. The aims of this research are documented as the following. First, this study shows the likelihood of the occurrence of factors that affect safety during tower crane installation and dismantling on construction sites in Vietnam. Second, this study determines the degree of influence of factors that affect safety during tower crane installation and dismantling on construction sites. Third, this study evaluates the safety risk factors by calculating a relative significant index score.

2. Literature Review

Safety of crane has been attracted many studies (Beavers, et. al., 2006; Butler, 1978; Fair, 1998; Häkkinen, 1993; Shapira & Simcha, 2009; Shepherd, Kahler, & Cross, 2000; Suruda, et. al., 1999; Tomakov, et. al., 2018; Salihu, Aliyu & Abubakar, 2020), in which there are a few studies on factors that affect safety with tower cranes on construction sites. Neitzel, Seixas, & Ren (2001) reviewed available information on tower crane injuries and made recommendations for improved tower crane injury prevention. Showing and analysing factors that affect the safety of tower cranes on construction sites in the United States were done by Shapira & Lyachin (2009). This study showed 21 safety risk factors for tower crane operations on construction sites, including four categories: safety management, project conditions, human factors, and the environment. Shapira & Simcha (2009) evalueted factor weights that affect safety with tower crane operations on construction sites by using the analytic hierarchy process (AHP) model. Shapira & Simcha (2009) used an integrative model that evaluated the quantity of safety factors with tower cranes on construction sites. Tam & Fung (2011). used a questionnaire survey and interviews to identify the safety risk factors of tower crane operations in Hong Kong.

However, these studies have mostly focused on the operation of cranes rather than on their installation and dismantling. Li, Chan, & Skitmore (2012) showed a safety training method for tower crane dismantlement and the results point out that the proposed method is generally better than the traditional methods. Shin (2015) investigated safety risk factors during tower crane installation and dismantling on construction sites in Koria by reviewing 38 fatal accidents relating to tower cranes that happened from 2001 to 2011. This study was done by evaluating fatal accident causes and interviewing tower crane-related people. The results indicated that human error is the most important cause of accidents during tower crane installation and dismantling and five major factors are included: (i) corruption of parts of the tower cranes during storage; (ii) lack of necessary materials for installation and dismantling; (iii) erectors and dismantlers lack knowledge and skills; (iv) bad working conditions, for example space and time constraints; and (v) work site with insufficient supervision. Salihu, Aliyu, & Abubakar (2020). evaluated safety risk factors of tower crane installation and dismantling on construction sites in Nigeria by determining their likelihood of occurrence and degree of influence and also showed the most significant factors. This study was conducted by using a total of 57 questionnaires with 21 factors. These questionnaires were sent to Kaduna, Abuja and Lagos. The paper showed that the most likely factor was the abrasion of components of the tower crane and the highest level of influence was the break of a wire rope during tower crane dismantling. The break of a wire rope during tower crane dismantling is the highest safety risk

factor of 21 factors that affect safety occurring on tower crane installation and dismantling on construction sites in Nigeria.

3. Research Methodology

The research process and methodology are shown in Fig. 1. The purpose of the study is to investigate the likelihood of occurrence and degree of influence of safety risk factors and evaluate safety risk factors occurring on tower crane installation and dismantling on construction sites in Vietnam. The research uses 21 factors that were identified by a previous study as in Table 1. A suitable-structured questionnaire was produced and sent to construction sites and construction companies that use tower cranes to collect data. The questionnaire measures the likelihood of occurrence and degree of influence of the factors by using a five point Likert scale. A total of 100 questionnaires were sent to practitioners who are directly involved in the tower crane-related process such as installation and dismantling workers; crane operators; workers performing tower crane-related work; safety managers, equipment managers. The research uses MS excel to treat data and then proposes recommendations.

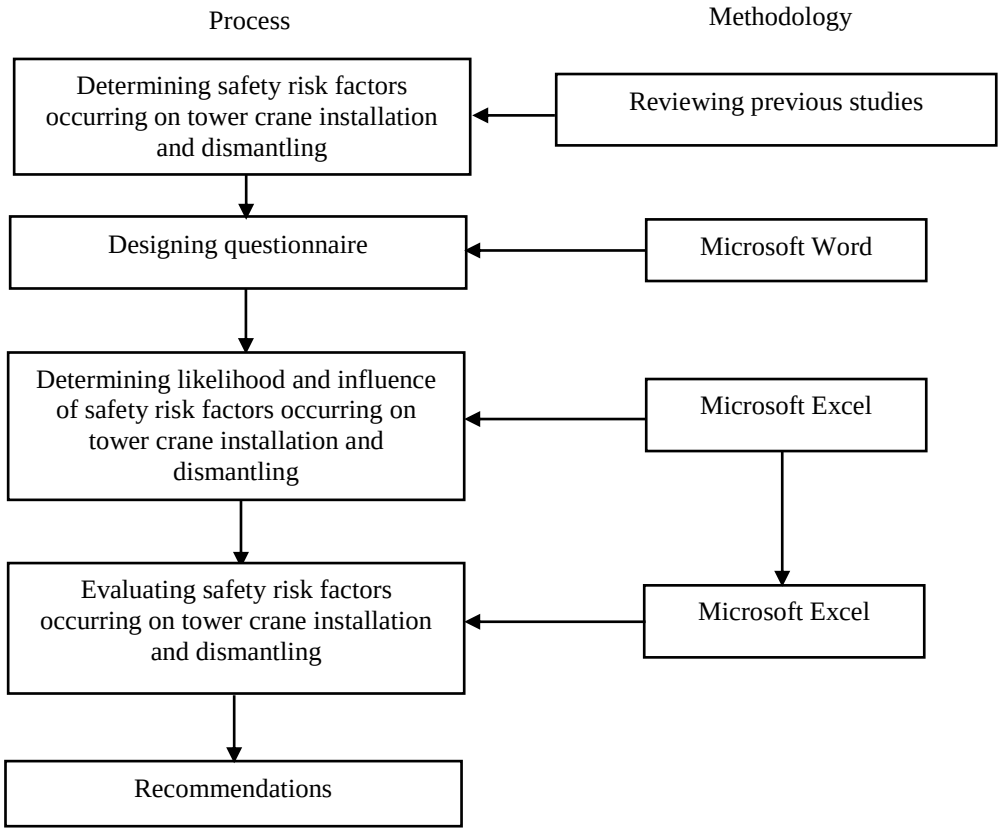

Fig. 1 - The research process and methodology

Table 1 - Safety risk factors occurring on tower crane installation and dismantling (Salihu, Aliyu, & Abubakar 2020)

No	Factors
1	Lack of workers to perform the work correctly and safely.
2	Installation and dismantling workers often leave the work due to hard working condition.
3	Time constraints are requested by investor, principal contractor or employer.
4	Trying to finish the work earlier than the time required for performing the work safely.
5	Usually skipping safety procedures or rules required with various reasons.
6	Lack of workers competence.
7	Insufficient instruction and supervision at construction sites.
8	Contractors do not know the necessity to ensure the safety of tower crane installation and dismantling.
9	Construction sites with unreasonable condition (ground conditions, working space, environment and restrictions).
10	Reducing quality of tower cranes part (components).

11 Workers character (installation and dismantling workers).
12 Overloading with objects exceeding the tower crane load limit.
13 Tower crane operators are not enough experiences.
14 Work procedures in manuals for the tower cranes installation and dismantling are not followed.
15 Malfunction of a tower crane.
16 Buckling of a telescopic cage.
17 Break of a wire rope occurring on dismantling.
18 Lack of working platforms.
19 Components have not incompatibility.
20 Dropping items.
21 Components of tower crane such as bolts, nuts, or pins have wear and tear.

4. Results and Discussion

4.1 Respondents Profile

Seventy eight responses were received and it obtained a response rate of about 71%. Table 2 presents the personal details of the respondents such as their nature of job, educational qualification and years of experience. Installation and dismantling workers on the tower cranes have a higher representation of 52.6% and safety managers have the least representation of 10.3%. All the respondents have at least a post-secondary education. Secondary graduation has a higher representation of 66.7% and bachelor has the least representation of 7.7%. 51% of the respondents have from 6 to 10 years, and from 16 to 20 years of working experience with tower cranes on construction sites, which account for about 26.9% and 24.4% respectively of the survey. About 10.3%, 16.6% and 21.8% of the respondents have working experience with tower cranes on construction sites with from 11 to 15 years , over 20 years, and from 0 to 5 years, respectively.

Table 2 - Respondents profile

No	Iterm	Number	Percentage
	Job description		
1	Safety managers	8	10.3
2	Equipment managers	9	11.5
3	Installation and dismantling workers	41	52.6
4	Craine operator	11	14.1
5	Worker performing tower crane-related work	9	11.5
	Total	**78**	**100**
	Educational qualification		
1	High school	9	11.5
2	Secondary graduation	52	66.7
3	Bachelors	6	7.7
4	MSc	11	14.1
	Total	**78**	**100**
	Years of experience		
1	0-5	17	21.8
2	6-10	21	26.9
3	11-15	8	10.3
4	16-20	19	24.4
5	Over 20	13	16.6
	Total	**78**	**100**

4.2 Likelihood of Occurrence for Safety Risk Factor

Table 3 presents the likelihood of occurrence for each safety risk factor as scored by the respondents based on a five point Likert scale. Mean values and standard deviation were calculated to help rank the factors that have the same mean value. Table 3 shows the assessment of the likelihood of occurrence of each factor and this shows that all factors have a mean value of > 2.0 and the most likely factor is "Time constraints are requested by investor, principal contractor or employer." with a mean value of 3.6 and the least likely factor is "Components have no incompatibility." with a mean value of 2.13. This implies that time for installing and dismantling tower cranes in Vietnam is usually not enough. However, previous studies showed that "Components of tower crane such as bolts, nuts, or pins have wear and tear." and "Work procedures in manuals for the tower cranes installation and dismantling are not followed." are the most likely factors that can result to accidents on construction sites in Koria and Negeria (Shin, 2015; Salihu, Aliyu, & Abubakar, 2020). Table 3 also shows the first four (4) factors that had mean values ≥ 3.0 including: "Time constraints are requested by investor, principal contractor or employer" (mean value of 3.60); "Trying to finish the work earlier than the time required for performing the work safely" (mean value of 3.14); "Dropping items" (mean value of 3.06); and "Construction sites with unreasonable condition (ground conditions, working space, environment and restrictions)" (mean value of 3.04). It means that these factors have the probability of appearing and may repeat sometimes. The factors from 5th to 21st positions had mean values of ≥ 2.0 indicating that they are unlikely to repeat but have a chance of appearing. This can conclude that all the above identified factors have the probability of appearing on construction sites.

Table 3 - Likelihood of occurrence of factors

No	Factors	Frequency									
		1	2	3	4	5	∑f	∑α	Mean	Std.Dev	Rank
1	Time constraints are requested by investor, principal contractor or employer.	3	9	23	24	19	78	281	3.6026	1.0971	1st
2	Trying to finish the work earlier than the time required for performing the work safely.	9	7	33	22	7	78	245	3.141	1.0898	2nd
3	Dropping items.	8	17	31	6	16	78	239	3.0641	1.2415	3rd
4	Construction sites with unreasonable condition (ground conditions, working space, environment and restrictions).	9	10	31	25	3	78	237	3.0385	1.0375	4th
5	Reducing quality of tower cranes part (components).	8	18	26	20	6	78	232	2.9744	1.1046	5th
6	Components of tower crane such as bolts, nuts, or pins have wear and tear.	8	26	20	9	15	78	231	2.9615	1.2837	6th
7	Malfunction of a tower crane.	8	20	31	14	5	78	222	2.8462	1.0454	7th
8	Installation and dismantling workers often leave the work due to hard working condition.	11	20	21	24	2	78	220	2.8205	1.1019	8th
9	Workers character (installation and dismantling workers).	13	18	27	14	6	78	217	2.86192	1.1613	9th
10	Work procedures in manuals for the tower cranes installation and dismantling are not followed.	19	17	18	11	13	78	216	2.7692	1.4043	10th
11	Usually skipping safety procedures or rules required with various reasons.	16	15	23	23	1	78	212	2.7179	1.1384	11th
12	Lack of workers to perform the work correctly and safely.	20	10	29	16	3	78	206	2.641	1.184	12th
13	Insufficient instruction and supervision at construction sites.	17	20	16	25	0	78	205	2.6282	1.1522	13th
14	Buckling of a telescopic cage.	9	31	21	15	2	78	204	2.6154	1.0094	14th
15	Lack of workers competence.	13	26	24	12	3	78	200	2.5641	1.064	15th
16	Contractors do not know the necessity to ensure the safety of	19	18	22	18	1	78	198	2.5385	1.1361	16th

	tower crane installation and dismantling.										
17	Overloading with objects exceeding the tower crane load limit.	22	17	22	15	2	78	192	2.4615	1.1699	17th
18	Tower crane operators are not enough experiences	24	17	20	15	2	78	188	2.4103	1.1891	18th
19	Break of a wire rope occurring on dismantling.	20	20	30	5	3	78	185	2.3718	1.0582	19th
20	Lack of working platforms.	13	35	22	6	2	78	183	2.3462	0.9373	20th
21	Components have not incompatibility.	26	23	24	3	2	78	166	2.1282	1.0111	21st

1= Improbable; 2=Unlikely; 3=Possible; 4= Probable; and 5=Almost certain

4.3 Degree of Influence for Factors

The influence of each factor was evaluated by using a 5 point Likert scale. The diverse degree of influence of the factors were established if they arose, and then, the mean values were counted as in Table 4. Table 4 shows that all the factors had a degree of influence from minor injury to death. There were 13 factors which had degree of influence with a mean value >3.0. This implies that it can lead to major injury if it appears. The factor of break of a wire rope occurring on dismantling had the highest degree of impact with a mean value of 4.18 which implies that the resultant effect of this safety risk factor is very serious if it appears. It results in deaths, serious injuries, and other property, equipment, and machine damage, as well as extending the project schedule. The result is similar to a previous study, but it ahas highest degree of impact with a mean value of 4.63. There were 8 factors which had a degree of influence with a mean value from 2.21 to 2.91. In which, the factor of "Components have no incompatibility" had the lowest degree of influence with a mean value of 2.21 which implies that it can only lead to minor injury/ injuries if it appears. Usually skipping safety procedures or rules required for various reasons and overloading with objects exceeding the tower crane load limit are 11th and 17th probable factors to occur on construction sites, respectively as shown in Table 3. However, they have a high degree of influence. Overloading with objects exceeding the tower crane load limit was ranked 2nd and usually skipping safety procedures or rules required for various reasons was ranked 3rd as shown in Table 4.

Table 4 - Degree of influence of factors

No	Factors	Frequency								
		1	2	3	4	5	∑f	∑β	Mean	Rank
1	Break of a wire rope occurring on dismantling.	1	4	10	28	35	78	326	4.1794	1st
2	Overloading with objects exceeding the tower crane load limit.	10	8	14	18	28	78	280	3.5897	2nd
3	Usually skipping safety procedures or rules required with various reasons.	9	7	18	27	17	78	270	3.4615	3rd
4	Work procedures in manuals for the tower cranes installation and dismantling are not followed.	7	14	16	22	19	78	266	3.4103	4th
5	Lack of workers competence.	8	4	30	23	13	78	263	3.3718	5th
6	Contractors do not know the necessity to ensure the safety of tower crane installation and dismantling.	12	9	15	23	19	78	262	3.359	6th
7	Tower crane operators are not enough experiences.	13	6	19	21	19	78	261	3.3462	7th
8	Malfunction of a tower crane.	7	14	28	13	16	78	251	3.2179	8th
9	Reducing quality of tower cranes part (components).	8	13	19	33	5	78	249	3.1923	9th
10	Lack of workers to perform the work correctly and safely.	8	15	19	27	9	78	248	3.1795	10th
11	Dropping items.	9	11	26	25	7	78	244	3.1282	11th
12	Insufficient instruction and supervision at	16	8	20	24	10	78	238	3.0513	12th

	construction sites.									
13	Construction sites with unreasonable condition (ground conditions, working space, environment and restrictions).	13	14	22	17	12	78	235	3.0128	13th
14	Time constraints are requested by investor, principal contractor or employer.	15	11	26	18	8	78	227	2.9103	14th
15	Trying to finish the work earlier than the time required for performing the work safely.	21	8	22	20	7	78	218	2.7949	15th
16	Lack of working platforms.	19	18	15	14	12	78	216	2.7692	16th
17	Buckling of a telescopic cage.	18	19	19	8	14	78	215	2.7564	17th
18	Workers character (installation and dismantling workers).	16	21	17	18	6	78	211	2.7051	18th
19	Components of tower crane such as bolts, nuts, or pins have wear and tear.	27	14	22	7	8	78	189	2.4231	19th
20	Installation and dismantling workers often leave the work due to hard working condition.	29	14	21	9	5	78	181	2.3205	20th
21	Components have not incompatibility.	32	16	18	6	6	78	172	2.2051	21st

1=Negligible; 2=Minor Injury; 3= Major Injury; 4=Fatality; and 5= Multiple Fatality

4.4 Evaluation of Factors

The safety risk factors were calculated by showing their relative significant index score (RSIS). The relative significant index score is a function of the likelihood of occurrence and the degree of influence and can be calculated by the total significance score for all risks divided by the number of the respondent. These RSIS represent the relative importance of these factors. The relative importance between one factor and the other is expressed through their relative score. The results were then compared against a standard risk developed by Construction Plant Hire Association (CPA) (2011). The symbols in Table 5 are defined as follows: $\sum\alpha$ (likelihood risk score), $\sum\beta$ (degree of influence risk score), $\sum$RS (combined risk score), and N (population). Table 5 shows that "Time constraints are requested by investor, principal contractor or employer" had the highest RSIS of 10.48 meanwhile "Components have not incompatibility" had the lowest RSIS of 4.69. There were 15 factors with a high RSIS > 8.0, implying moderate risk factors that require a suitable degree of controls with tower crane installation and dismantling-related works to prevent hazard and make construction sites safer.The factors ranked from 16th to 21st had RSIS of 7.49 – 4.69 respectively, which indicates low risk factors that are acceptable with no need for any control actions.

Table 5 - Evaluation of safety risk level

No	Factors	$\sum\alpha$	$\sum\beta$	$\sum$RS	N	RSIS	Rank	Risk level
1	Time constraints are requested by investor, principal contractor or employer.	281	227	63787	6084	10.484	1st	Moderate
2	Break of a wire rope occurring on dismantling.	185	326	60310	6084	9.9128	2nd	Moderate
3	Dropping items.	239	244	58316	6084	9.5851	3rd	Moderate
4	Reducing quality of tower cranes part (components).	232	248	57536	6084	9.4569	4th	Moderate
5	Work procedures in manuals for the tower cranes installation and dismantling are not followed.	216	266	57456	6084	9.4438	5th	Moderate
6	Usually skipping safety procedures or rules required with various reasons.	212	270	57240	6084	9.4083	6th	Moderate
7	Malfunction of a tower crane.	222	251	55722	6084	9.1588	7th	Moderate

8	Construction sites with unreasonable condition (ground conditions, working space, environment and restrictions).	237	235	55695	6084	9.1543	8th	Moderate
9	Overloading with objects exceeding the tower crane load limit.	192	280	53760	6084	8.8363	9th	Moderate
10	Trying to finish the work earlier than the time required for performing the work safely.	245	218	53410	6084	8.7788	10th	Moderate
11	Lack of workers competence.	200	263	52600	6084	8.6456	11th	Moderate
12	Contractors do not know the necessity to ensure the safety of tower crane installation and dismantling.	198	262	51876	6084	8.5266	12th	Moderate
13	Lack of workers to perform the work correctly and safely.	206	248	51088	6084	8.3971	13th	Moderate
14	Tower crane operators are not enough experiences.	188	261	49068	6084	8.0651	14th	Moderate
15	Insufficient instruction and supervision at construction sites.	205	238	48790	6084	8.0194	15th	Moderate
16	Workers character (installation and dismantling workers).	216	211	45576	6084	7.4911	16th	Low
17	Buckling of a telescopic cage.	204	215	43860	6084	7.2091	17th	Low
18	Components of tower crane such as bolts, nuts, or pins have wear and tear.	231	189	43659	6084	7.176	18th	Low
19	Installation and dismantling workers often leave the work due to hard working condition.	220	181	39820	6084	6.5450	19th	Low
20	Lack of working platforms.	183	216	39528	6084	6.4970	20th	Low
21	Components have not incompatibility.	166	172	28552	6084	4.6930	21st	Low

5. Conclusions

The safety risk factors occurring on tower crane installation and dismantling on construction sites in Vietnam were evaluated. The results show that all 21 identified factors in previous studies have a likelihood of occurring on construction sites in Vietnam, in which the most probable factor is "Time constraints are requested by investor, principal contractor or employer" with a mean value of 3.6 and the break of a wire rope occurring on dismantling had the highest degree of influence with a mean value of 4.18. There are 15/21 facors with a moderate risk level that is acceptable but, requires suitable controls to make the construction sites safer. "Time constraints are requested by investor, principal contractor or employer" had the highest RSIS of 10.484. This research only focused on factors that affect the safety of tower cranes occurring on installation and dismantling. Factors that affect the safety of tower cranes during operation on construction sites in Vietnam are a valuable direction for future research.

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