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Importance Ranking of Accident Factors of Construction Tower Crane by AHP Technique

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Abstract

In Korea construction industry, the increase of tower crane's usage continuously and the accidents of tower crane are increasing simultaneously. But research on tower crane is insufficient for reducing the tower crane accident. This study aims to derive the importance ranking of accident factors of cab-control tower crane by AHP analysis. AHP survey was conducted on experts such as construction engineer, construction manager, safety engineer, and tower crane operator, who have more than 10-year career. The results of AHP analysis reveal that top ranking factor of cab-control tower crane's accident is erection work. Therefore, the derived factors should be managed, and the priority measures taken for reducing the tower crane accidents according to the ranking of accident factors.

Keywords

Cab-Control Tower Crane, Analytic Hierarchy Process, Importance Ranking of Accident Factors

1. Introduction

The use of tower crane in construction sites has constantly increased since its first introduction in the 1980's. According to statistics on the construction machinery status of the Ministry of Land, Infrastructure and Transport, in 2015, Korea had 3408 cab-control tower cranes (CC T/C). The number of tower cranes increased to 4385 CC T/C by 22 percent in 2019 [1]. Consequently, as the number of tower crane used in construction site has increased steadily, there are potential accident factors of tower crane itself. That is, tower crane is dangerous and their various risk factors are inherent in the erection, lifting, and dismantling works [2]. Every year, the number of tower crane-related accidents in con-

struction sites continues to increase. The occurrence of serious accidents regarding tower crane is 9 cases in 2016, 7 cases in 2017, 6 cases in 2018, and 8 cases in 2019 [3].

The government has made various efforts to reduce tower crane-related disasters. For example, the government revised the enforcement regulations of the Construction Equipment Management Act from October 2019 in order to prevent the occurrence of tower crane accidents [3]. In addition, academia has conducted research on various factors of accidents by analyzing tower crane accident case, etc. [4] [5] [6] for reducing tower crane-related disasters. The CC T/C is that equipment aging, insufficient work management, violation of work guidelines and safety rules, and lack of communication were the main causes of accidents [7]. Despite these efforts, it was not enough to prevent continuously CC T/C accidents. Therefore, this study aimed to identify the risk factors and then the importance factors of CC T/C to derive the importance ranking.

In this study, AHP technique was adapted to derive the importance of each tower crane accident factor, for it is an effective way to prioritize the responses based on the experience of experts working in the construction site. The AHP survey has been conducted on the construction engineers, construction managers, safety managers, and tower crane operators that are expert of tower crane related experience for more than 10 years. The process of this study is as follows: Firstly, literature review was conducted such as accident factor of previous study and tower crane configuration, etc. Secondly, preliminary survey has been carried out to select the factors of tower crane accidents while the questions for the survey are drawn from literature review. The selected factors have been used in AHP questionnaire. Analytic Hierarchy Process (AHP) is a decision-making structured technique developed by T. Saaty in the early 1970s, reflecting the knowledge, experience, and intuition of respondents in pair-wise comparisons through the elements of the hierarchy of decision-making [8]. Thirdly, AHP analysis was performed. The importance of accident factors has been analyzed through AHP survey conducted on the construction engineers, construction managers, safety managers, and tower crane operators with more than 10 years of field experience. Fourthly, the importance of tower crane accidents was made ranking to prevent any accidents of tower crane.

2. Literature Review

2.1. Previous Research

Various studies related to the safety accidents of tower crane. The studies are shown in **Table 1**. Several studies related to tower crane accidents have been

Table 1. Literature review related to tower crane accidents.

Author	Major research subject
Aneziris *et al.* (2008) [9]	Risk analysis of the results of tower crane accidents using WORM (Workgroup Occupational Risk Model)

Continued

Kwon (2015) [10]	Suggest priority management targets through analysis using the tower crane accidents status and FMEA technique by types
Richard *et al.* (2001) [11]	Suggest a plan to prevent safety accidents by analyzing cases of tower crane safety accidents and safety procedures
Aviad *et al.* (2009) [12]	Propose the safety management plans through analysis using the importance and priority of each accident factor through AHP analysis
Cho (2017) [7]	Safety management data derived through analysis using the importance and priority of each accident factor through AHP analysis
Song (2018) [13]	Present the measures to improve safety management by identifying and analyzing types of accidents using tower crane major disaster case analysis and survey

conducted, but previous studies have mainly focused on the derivation of accident factors and tower crane management plans. That is, there are not enough studies that can be used for the management of tower crane accident by ranking the importance of accident factors.

2.2. Accident Factors of Tower Crane Presented in Previous Study

Until nowadays, various previous studies on the accidents factors of tower crane have been in progress, and the factors suggested in previous studies are shown in Table 2.

3. AHP Model of Tower Crane Accident Factors

3.1. Selected Accident Factors

For level 1 of AHP model, the 11 accident factors were selected from previous study as shown in Table 3. The 5-factors of level 2 such as dismantling work, lifting work, erection work, management factor and T/C machine factor were selected by interviewing with experts, who have more than 10 years of field experience, from 11 accident factors. The 25 factors extracted from previous studies for level 2 of AHP model were classified into the level 1 factors. Table 4 shows the accident factors assigned to the level 1 and level 2 of AHP model.

3.2. AHP Survey

As shown in Table 5, AHP analysis has been conducted on that a total of 44 surveys carried out on the experts with more than 10 years of experience. The survey respondents were 14 construction engineers, and the other respondents were 10 each. In addition, 43% of all respondents have more than 20 years of experience. The survey was conducted from March to May 2020, and a 9-point scale was used in the questionnaire to quantify in pairwise comparisons between factors.

4. The Results of AHP Survey

As the result of an AHP survey conducted among 14 construction engineers on

Table 2. Extracting accident factors of tower crane's accident in previous study.

Kwon (2015)	Lifting work/Erection work/Dismantling work/Climb work /Others work
Choi (2017)	Machine factor/Management factor/Erection·Dismantling·Climb factor/Operation factor
Song (2018)	Erection work/Climbing work/Dismantling work/Common
Kim (2018)	Erection work/Climb work/Tower carne operation

Table 3. Extracting accident factors of tower crane's accident by preliminary survey.

Extracted factors	Lifting work/Erection work/Dismantling work/Climb work/Others work/ On-site conditions/Process and construction period/Machine factor/ Management factor/Tower carne operation/Other

Table 4. Second level factors of AHP structure.

Level 1 factor	Level 2 factors of AHP structure for tower crane accident cab-tower crane
Dismantling work (F1)	F11: Poor understanding of risk factors during dismantling process F12: Bad tightening of bolts F13: Low skill level of dismantling workers
Lifting work (F2)	F21: Poor management of lifting objects and control of surroundings F22: Poor tying of the sling leg F23: Operator's bad visibility
Erection work (F3)	F31: Bad bolting brace/mast/telescopic F32: Failure to comply with safety rules and work guidelines for erection work F33: Insufficient skill in worker for erection work
Prime contractor's management (F4)	F41: Inappropriate personnel and equipment placement F42: Poor subcontractor technology management by process F45: Insufficient safety management of equipment and personnel
T/C machine (F5)	F51: Equipment aging F52: Crane operation error or failure F53: Problems of overseas parts procurement

Table 5. AHP questionnaire respondents.

	Distribution	Frequency (person)	(%)
Profession	Construction engineer	14	31
	Construction manager	10	23
	Safety engineer	10	23
	Tower crane operator	10	23
Careers	10 years - 20 years	25	57
	More than 20 years	19	43

the top rank factors of tower crane accidents, the dismantling work was the most important factor at 0.391 followed by lifting work 0.294, erection work 0.156, prime contractor's management 0.087. The T/C machine factor was the lowest at 0.072. The results of survey from construction managers, safety managers, and tower crane operators are shown in **Table 6**. As the results of the experts' responses

Table 6. Importance ranking of level 1 factors of AHP model.

Level 1 factor	Construction engineer		Construction manager		Safety engineer		Tower crane operator		Total	
	Wt	Rank	Wt	Rank	Wt	Rank	Wt	Rank	Wt	Rank
Dismantling work	0.391	1	0.090	5	0.100	5	0.099	5	0.170	5
Lifting work	0.294	2	0.293	1	0.121	4	0.146	4	0.214	3
Erection work	0.156	3	0.205	3	0.219	3	0.322	1	0.226	1
Prime contractor's management	0.087	4	0.164	4	0.254	2	0.194	3	0.175	4
T/C machine	0.072	5	0.248	2	0.305	1	0.239	2	0.216	2

summarized from the AHP survey, erection work was the 1st rank factor at 0.226 followed by T/C operator 0.216, lifting work 0.214, prime contractor's management 0.175 while dismantling work was the lowest at 0.170.

As the result of AHP survey conducted among construction engineers on the safety accident factors regarding level 2 of AHP model, the importance for poor understanding of risk factors during dismantling process was the 1st rank followed by operator's bad visibility and low skill level of dismantling workers. The results of AHP analysis on the level 2 accident factors of construction managers, safety managers, and tower crane operators are as shown in Table 7.

The importance values were collected from the opinions of the experts on safety accident factors regarding tower cranes. The factors regarding CC T/C appeared important in the order they were listed as follows; operator's bad visibility, bad bolting brace/mast/telescopic, poor subcontracting technology management by process failure to comply with safety rules and work guidelines for installation work, problems of overseas parts procurement, and poor understanding of risk factors during dismantling process.

5. Discussion and Conclusions

Despite the efforts of each field to reduce accidents regarding tower cranes, serious disasters are not decreasing. In addition, as the usage of tower cranes continues to increase, the number of accidents is increasing. This study has been conducted to prevent tower crane-related accidents by deriving the risk factors of CC T/C the importance of each factor to be used as a reference. As the analysis result of the 1st level (the accident weight) of AHP model, the accident factor weight of erection of the tower crane is largest, followed by the T/C machine.

The final ranking of tower crane accidents was derived by multiplying the weight of the 1st level and the weight of the 2nd level. As its result, the final ranking of accident factors was F23 (Operator's bad visibility), F31 (Bad bolting brace/mast/telescopic), F42 (Poor subcontractor technology management by process), F53 (Problems of overseas parts procurement) in order. The operator's visibility of the location where is target object and the surrounding conditions are more important than any other factors. If the operator has no visibility, the operator simply has to rely on the hand signal or the radio sound from other

Table 7. Importance ranking of tower crane's accident factors.

First Level	Second level (sub factor)	Construction engineer		Construction manager		Safety engineer		Tower crane operator		Total	
		Wt	R	Wt	R	Wt	R	Wt	R	Wt	R
	F11	0.204	1	0.039	10	0.028	12	0.048	8	0.073	6
F1	F12	0.066	6	0.030	13	0.052	10	0.011	15	0.048	12
	F13	0.121	3	0.021	15	0.020	13	0.040	10	0.049	11
	F21	0.042	8	0.117	4	0.015	14	0.096	4	0.071	8
F2	F22	0.107	4	0.041	9	0.012	15	0.011	14	0.037	15
	F23	0.144	2	0.135	1	0.093	4	0.039	11	0.107	1
	F31	0.081	5	0.122	2	0.126	2	0.116	3	0.098	2
F3	F32	0.040	9	0.057	7	0.054	9	0.180	1	0.080	4
	F33	0.036	10	0.027	14	0.040	11	0.085	6	0.046	13
	F41	0.018	14	0.039	11	0.067	7	0.044	9	0.042	14
F4	F42	0.047	7	0.036	12	0.123	3	0.131	2	0.084	3
	F43	0.022	13	0.089	5	0.064	8	0.019	13	0.050	10
	F51	0.023	12	0.119	3	0.079	5	0.079	7	0.064	9
F5	F52	0.018	15	0.083	6	0.075	6	0.026	12	0.071	7
	F53	0.031	11	0.047	8	0.152	1	0.090	5	0.075	5

workers. These problems are difficult for the related managers such as safety managers to accurately judge, and because they have no choice but to rely on the judgment of the tower crane operator, it is necessary to attach a high-performance camera to the trolley of tower crane. The problems of F31 (Bad bolting brace/mast/telescopic) and F42 (Poor subcontracting technology management by process) are related to the responsibilities and skills of the erection worker. This factor is a management problem of construction site, and it is believed that it will be possible by following the manual of erection work and improving the skills of the erection worker, so it can be solved by continuous education for the erection workers. The next factor is the quality problem of tower crane parts imported from overseas. As tower cranes have been manufactured long time ago, old parts of tower crane have been frequently replaced. Therefore, it is necessary to have a system that can guarantee the quality of parts in government. This is because tower crane renters prefer to use parts that are cheaper than the quality of parts to increase profits.

Tower crane accidents are not caused by one or two factors, but occur when several factors are being complexity and consistently. If you want not to occur of tower crane accident, not one or two accident factors is(are) be managed or removed, but several factors must be managed or removed continuously and simultaneously. Therefore, in order to reduce tower crane accidents, it would be possible if the results of this study were used to continuously manage the factors

of tower crane accidents in construction site management. In the future, according to change of the type of tower crane used in construction site in order to reality reduce tower crane accidents in realty, it is necessary to further study the accident factors corresponding to this.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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