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A Risk Analysis and Ranking Application for Lifting Vehicles Used in Construction Sites with Integrated AHP and Fine-Kinney Approach

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ABSTRACT

Risk scoring methods applied in risk assessments used in Turkey, differ from each other in terms of analysis methods, scoring the risks, presumption and sensitivity levels. This article aims to eliminate the effects of divergent results of different risk analyses of lifting equipments used in the building industry and develop a practical hybrid risk analysis and ranking method. In this study risks of lifting equipments used in the building industry were scored by conventional Fine-Kenney risk analysis method first. Secondly, with the experience of previous accidents on construction sites, the reasons of accidents were sorted into 7 main criteria, which being 'Demographic', 'Behavioral', 'Machine Related', 'Working Environment Related', 'Economical', 'Administrative' and 'Organizational' criteria and related sub-criteria. Developing these criteria was supported by the experience of inspections carried out by labour inspectors. The weighted scores of these criteria were calculated by AHP method using a questionnaire applied to 14 experienced labor inspectors. The weighted scores obtained by the analytical hierarchy process method (AHP) were multiplied by the scores obtained by Fine-Kinney risk assessment method and a new integrated risk assessment and ranking application was introduced. With this application, a different priority rank was created and which risk to be eliminated primarily was determined.

Keywords: analytical hierarchy process, lifting equipments, fine-kinney, occupational health and safety, integrated risk analysis, ranking method

INTRODUCTION

In recent years, the importance of construction has increased in the Turkish economy. According to TURKSTAT data, the ratio of construction sector in national income was 8.1% in 2014, 8.2% in 2015 and 8.6% in 2016. However, most of the fatal accidents occur in the construction sector inTurkey. According to Social Insurance Institution data, approximately 35% of deaths experienced in the construction sector every year. One of the most important reasons of serious accidents in construction cites is the lifting vehicles. These accidents also cause huge financial losses. Most of these accidents are easily prevented by calculating risks accurately based on risk assessment results.

With the Law No. 6331 (OH&S Act), risk assessment was made compulsory in all workplaces in Turkey in 2013. Widely used risk assessment methods on construction sites in Turkey are conventional '5x5 Matrix' (Matrix L) and 'Fine-Kinney' risk assessment methods. These methods are criticized because they contain subjective evaluations. Risk scores calculated in these risk assessment methods, the confidence level remains low depending on the person's knowledge and experience that the risk assessment. The success of the risk assessments made by these methods depends on the knowledge and experience of the expert. This reduces the success of these methods in calculating risks.

Multi-criteria decision making (MCDM) is a commonly used method to solve problems that arise when there are many criteria in the decision-making process. MCDM methods are frequently used in the solution of occupational health and safety problems and risk assessment studies. In this study, it is aimed to integrate Fine-Kinney method with AHP method. Firstly, the risks arising from the lifting vehicles were analyzed and scored by Fine-Kinney risk assessment method. In the second stage the weights of the hazard criterias were calculated by Analytical Hierarchy Process (AHP) method. At the last stage, the risk ranking was formed by multiplying the Fine-Kinney risk scores with the global weighted scores of each sub-criterion.

The main and sub-criteria used in the calculation of risk scores were determined by examining 1800 occupational accidents between 2015-2018 which resulted mortality. These main hazard criteria include; 'demographic', 'behavioral', 'working environment', 'machinery', 'organizational', 'managerial', 'economic' and their sub-criteria.

The data used in calculation of the weighted scores of hazard criteria with AHP method was obtained with a questionnaire applied to experienced labor inspectors. Global weighted scores of each sub-criterion were integrated into the Fine-Kinney risk analysis and the current risks were ranked according to the new risk scores and presented in a comparative chart.

The aim of the study is to increase the numerical sensitivity of risk scores obtained in traditional risk analysis methods, to determine different risk scores for the hazards calculated with the same risk scores as Fine-Kinney, and to determine a ranking in terms of the measures to be taken for these hazards. Thus, it is aimed to provide a guiding tool for occupational safety experts, managers and employers in order to determine the order of occupational health and safety measures in workplaces and to help planning the occupational health and safety measures.

RESEARCH METHODS

Analytical Hierarchy Process Method

In order to rank the alternatives or to choose the most suitable alternative, the process of evaluating the existing alternatives using quantitative and qualitative criteria is defined as multi-criteria decision making. The aim of the process is to find the most suitable option among the identified alternatives. Since multi-criteria decision making is used to rank alternatives with more than one criterion, it is a frequently used method to solve problems that occur in situations where there are many criteria and conflicting situations in the decision-making process [9].

The Analytical Hierarchy Method (AHP) was introduced by Thomas L. Saaty in the 1970s to solve a specific programming problem. This hierarchical structure created with the AHP aims to making the best decision or choosing the best alternative in the top of the hierarchy. As the lower levels are reached, the features that contribute to the purpose and the details of these features are seen. Decision options creates the lowest level. AHP is a theory of measurement based on a double comparison of alternatives to a common criterion and provides significant assistance to decision makers for eliminating multi-choice and multi-criteria problems. AHP problems are formed by a hierarchical structure consisting of objectives, criteria, possible sub-criterion levels and alternatives for each problem [20, 21].

Zhao [26] describes the AHP process in five steps:

- Step 1: Create a decision hierarchy by separating the problem into decision elements (attributes),
- Step 2: To compare the elements of decision to collect input,
- Step 3: Determining whether the input data is fulfilled with the 'Consistency Test'
- Step 4: Calculate the relative weight of decision elements,
- Step 5: Collect the weighted points of each decision element and list the decision alternatives.

This method has been used in many areas such as employee health, occupational safety, fire and performance measurement at workplaces. Multi-criteria decision making and risk ranking methods are also frequently used in researches on occupational health and safety [3, 6, 11, 12, 13, 24].

Prior to this study, several studies on integrated risk assessment were carried out under different outlooks. Integrated risk assessment practices are frequently encountered in construction works [1, 2, 4, 10, 16, 17, 18, 19, 22, 23]. However, there are few studies conducted in other areas other than construction with the approach of AHP and Fine-Kinney. For example, in a large machine manufacturing company, an application was proposed with the integrated AHP Fine-Kinney approach in the assessment of OHS risks [15]. The integrated AHP Fine-Kinney approach was also similarly used in assessing the risks in rail transport [7], in assessing the risks in the maintenance of ballast tanks [25]; and to identify and calculate the risk priority of each hazard in an arms manufacturing company [8]. However, in the literature, no risk assessment studies with AHP and Fine-Kinney approach related to lifting vehicles or construction works.

This study aimed to calculate the importance level of each hazard criterion according to the opinions of expert labor inspectors and to integrate the weighted risk scores calculated with AHP in Fine-Kinney risk analysis application. With this method, new and hybrid risk scores are calculated for the lifting tools used in construction sites. Thus, the existing risks are more sensitively ranked and the negative impacts that may arise from the knowledge and experience of the persons preparing the risk assessment are reduced.

With this method, the risks associated with lifting vehicles are calculated by quantitative method and the sensitivity of the risk assessment is increased. Quantitative information is provided to support occupational health and safety experts in determining the measures and priorities to be taken at the site and planning preventive studies.

Fine-Kinney Risk Assessment Method

Fine-Kinney method was first proposed in 1971 by Fine W.T. as a method of risk assessment based on mathematical calculation with a study called ‘Mathematical Assessment for the Control of Hazards’. In 1976, Kinney G.F. and Wiruth A.D., further developed under the name of ‘Practical Risk Analysis for Occupational Safety Management’ [5, 14]. In Fine-Kinney method, as in other risk assessment methods, it is a technique used to determine the order of implementation of the measures according to the ranking of the risks and where to use the resources first. Unlike other methods, it takes into account the frequency scale by taking into account the frequency of occurrence of the hazards. The method is applied as a quantitative method and its reliability is increased according to qualitative methods.

In Fine-Kinney method, there are three risk scales: Probability (P), Frequency (F) and Severty (S). Numerical values corresponding to verbal expressions are used. In applying this method, the risk score is calculated by finding the numerical values related to the hazards from the tables and multiplying the values. According to the method, a hazard is calculated with the formula: Risk Score (R) = Probability (P) x Frequency (F) x Severty (S) [5, 14].

Probability in Fine-Kinney risk assessment method; the possibility of an undesirable hazard which may result damage in health or property. The probability values are graded between 0.1 and 10 and the probability value is determined by evaluating whether the measures taken in the workplace are sufficient to prevent the occurrence of damages.

Frequency is the frequency of exposure to a certain period of time. In the method, the frequency values are defined between 0.5 and 10. When determining the frequency value, the frequency of exposure should be taken into consideration when doing the work, not the frequency of the work.

Severty is the estimated damage to human and/or the environment. In the method, the severity values are graded between 1 and 100 values, and if there is any doubt about the severity of the incident or if it is unstable, the higher score should be given.

Total Risk Score is obtained by multiplying the probability, frequency and severity values of the hazards at working areas. As shown in Table 1, the level of risk is determined by looking at the range of the risk score obtained. According to the

Table 1. Desicion and action based on risk level

Rank	Risk Value	Decision	Action
1	R < 20	Acceptable Risk	Emergency measures may not be necessary
2	20 < R < 70	Risk	Action plan must be taken
3	70 < R < 200	Important Risk	Must be carrefully monitored and removed by annual action plan
4	200 < R < 400	High Risk	Should be eliminated by taking into the short-term action plan
5	R > 400	Very High Risk	Take immediate measures by suspending work

results of risk scores, the measures to be taken and the priority order may be determined according to the principles of occupational health and safety.

APPLICATION

Data Collection Method and Prioritization of the Hazards with Ahp

In order to obtain data for AHP application within the scope of the research, the main hazard criteria and sub-criteria (hazards) were determined as a result of the examination of 1800 fatal accidents which occurred in construction sites between 2015-2018 and a questionnaire was prepared in order to calculate the weights of these criteria. The questionnaire is presented in a simplified way to compare the hazard criterias with each other, as shown in Table 2.

Responses were gathered in separate forms with personal interviews from highly experienced labor inspectors in the Ministry of Labor Department of Guidance and Inspection, who are experts in safety and occupational accidents and inspected at least 50 different enterprises each year.

After the hazards were determined and the categories were formed, each hazard was compared with itself using the AHP method, and AHP table was formed. While forming the AHP tables, the experience of an expert could be exploited, and the AHP comparison tables could be formed by one expert. If there is more than one expert, an assessment is made based on each expert and then the average AHP value of experts can be found using the arithmetic average of the AHP values of the experts.

In this study, the questionnaire was applied to 14 labor inspectors. The purpose and the nature of the questionnaire and its intended results are described in detail. Participants were asked to determine the degree of severity according to the other criterion specified at the end of the line. The AHP method was used to calculate the hazard criteria weights according to the scores in the questionnaire through the matrix. Calculation was made based on each expert and used arithmetic average of the AHP values of the experts.

In questionnaire; 'Mechanical Criteria', 'Economic Criteria', 'Behavioral Criteria', 'Work Environment Criteria', 'Administrative Criteria', 'Demographic Criteria' and 'Organizational Criteria' are presented in the form of comparative headings for the calculation of the weighted scores of the main hazard criteria and their sub-criteria.

In order to calculate the total relative weight of each hazard criterion, the main hazard criteria were divided into various criteria and compared with the surveys conducted by the labor inspectors. Then, the overall weighted average scores of all sub-criteria, the total weighted scores of the main criteria and the total weighted scores of the sub-criteria within the main criteria were calculated.

Hazard criteria weights calculated by AHP method are presented in Table 3:

Integration of Ahp Method with Fine-Kinney Risk Assessment Method

Firstly, the risk scores calculated by the Fine-Kinney method are ranked from large to small according to the size of the risk scores. Then, the hazard definitions stated in the risk analysis table are divided into classes according to the criteria specified in the survey conducted by the labor inspectors. During this classification, more than 200 construction site audit experience and occupational accident statistics were used. The Fine-Kinney risk score in the risk assessment table are multiplied by the global weight score of that criterion, which is the subclass category. The new risk scores updated with AHP are presented in tables according to their risk scores, including the scores obtained by the Fine-Kinney method, sorted by size (See Table 4 Risk score and ranking table prepared by integrated Fine-Kinney-AHP method).

The study was carried out as follows;

- In the first stage, hazards were categorized and risk scores were calculated by using the Fine-Kinney method on lifting vehicles together with occupational safety experts in construction sites.
- In the second stage, by taking into account the accident statistics related to lifting vehicles,

Table 2. Two-way comparison scale

X	9	7	5	3	1	3	5	7	9	Y
	Absolute Important	Very Important	Important	Little Important	Unimportant	Little Important	Important	Very Important	Absolute Important	

the main hazard criteria related to lifting vehicles and their sub-criteria were determined.
- In the third stage, severity of these main and sub-criteria was determined by a questionnaire applied to 14 labor inspectors and results were calculated by AHP method. Weighted (significance) scores of each main criterion and sub criterion were determined.
- In the fourth stage, the weighted global (overall) scores calculated for each sub-criterion were multiplied by the risk scores calculated by the Fine-Kinney for each hazard.
- In the fifth stage, an integrated risk assessment score table was formed. The risks arising from the lifting equipment were ranked according to the risk score.

Table 3. Hazard criteria weights calculated by AHP

Main Criteria	Sub-criteria	Global (Overall) Weighted Score of Sub-Criteria	Total Weighted Score of Main Criteria	Weighted Score of the Sub-Criteria in the Main Criteria
Mechanical Criteria % 22.69	Design Errors	0.079073041	0.226930437	0.348446165
	Insufficiency of Periodic Controls of Lifting Vehicles	0.043122856		0.19002676
	Lack of Machine Maintenance	0.037396803		0.164794125
	Installation and Operation Information of the Machine	0.035854857		0.157999332
	Malfunctions	0.031482881		0.138733618
Economic Criteria % 17.34	Uncontrolled Growth of Construction Sector (Lack of specialization)	0.069953745	0.173460464	0.403283511
	Lack of Adaptation to Technology	0.045694553		0.26342921
	Budget Deficiency	0.027276564		0.157249457
	Income Level of Employees	0.019408395		0.111889443
	Wage System Mistakes	0.011127208		0.064148379
Behavioral Criteria % 16.51	Lack of Awareness	0.035100108	0.165157929	0.212524507
	Health problems	0.026454907		0.160179453
	Tiredness	0.02484593		0.150437406
	Inability	0.024690546		0.14949658
	Lack of Experience	0.024064225		0.14570433
	Family Problems	0.01147748		0.069493967
	Carelessness	0.010087787		0.061079643
	Lack of Motivation	0.008436946		0.051084113
Administrative Criteria % 15.46	OHS Approach of Employer	0.050936546	0.154660857	0.329343486
	Production Pressure	0.043196415		0.279297656
	Lack of Audit	0.02382587		0.154052363
	Discipline Deficiency	0.020562678		0.132953343
	Insufficiency of Penalties	0.016139348		0.104353151
Work Environment Criteria % 12.08	Hazardous Elements in the Working Area	0.031065224	0.12081453	0.257131522
	Working Area Clutter	0.028715163		0.237679719
	Working Area Shortness	0.0207752		0.171959449
	Lack of Information on the Working Area	0.017796858		0.147307267
	Land Structure	0.014717459		0.121818617
	Climatic Effects	0.007744625		0.064103426
Organizational Criteria % 11.78	Lack of OHS Training	0.033976084	0.117823218	0.288364931
	OHS Services Insufficiency	0.022433729		0.1904016
	Lack of Internal Audit and Supervision	0.021587244		0.183217235
	Lack of Communication	0.019208973		0.163032155
	Personnel Deficiency	0.016219511		0.137659716
	Lack of Documentation	0.004397677		0.037324363
Demographic Criteria % 4.11	Education level	0.015011851	0.041152566	0.364785289
	Working hours	0.014978964		0.363986143
	Migrant labor	0.005738345		0.139440752
	Age	0.003681603		0.089462305
	Gender	0.001741803		0.04232551

Table 4. Risk score and ranking table prepared by integrated Fine-Kinney-AHP method

Ranking with Fine-Kinney	Global (overall) weighted score of sub-criterion (GWS)	Definition of hazard	Fine-Kinney risk score (FRS)	Integrated risk score (IRS) IRS= GWSxFRS	New ranking
3	0.0431228557110697 (Insufficiency of Periodic Controls)	Failure to check bolts	3600	155.2422806	1
1	0.0207751999630086 (Narrowness of the Working Area)	Working on the passageways of the load	6000	124.6511998	2
2	0.0207751999630086 (Narrowness of the Working Area)	Employees under load	6000	124.6511998	3
7	0.0431228557110697 (Insufficiency of Periodic Controls)	Failure to control the brakes	1800	77.62114028	4
8	0.0431228557110697 (Insufficiency of Periodic Controls)	Hook and hook block not controlled	1800	77.62114028	5
9	0.0431228557110697 (Insufficiency of Periodic Controls)	Chain and chain wheel not controlled	1800	77.62114028	6
24	0.0790730405706215 (Design Errors)	No warning signal on crane movement	900	71.16573651	7
27	0.0790730405706215 (Design Errors)	Lack of lighting of the load hook	900	71.16573651	8
29	0.0790730405706215 (Design Errors)	Improper hooks	900	71.16573651	9
30	0.0790730405706215 (Design Errors)	Improper of ropes	900	71.16573651	10
31	0.0790730405706215 (Design Errors)	Chains are not in accordance with standards	900	71.16573651	11
39	0.0790730405706215 (Design Errors)	Rope overrun out of the drum. rope ejection	900	71.16573651	12
40	0.0790730405706215 (Design Errors)	Get rid of the rope from drum	900	71.16573651	13
41	0.0790730405706215 (Design Errors)	Contact of the load on the drum	900	71.16573651	14
43	0.0790730405706215 (Design Errors)	The chain is not in accordance with the standards	900	71.16573651	15
44	0.0790730405706215 (Design Errors)	Lack of sieve ropes according to the standards	900	71.16573651	16
45	0.0790730405706215 (Design Errors)	Lack of steel ropes according to the standards	900	71.16573651	17
46	0.0790730405706215 (Design Errors)	Hooks do not comply with standards	900	71.16573651	18
47	0.0790730405706215 (Design Errors)	Slingshots not conforming to standards	900	71.16573651	19
12	0.0373968029068827 (Lack of Maintenance)	Not performing the periodic controls of the cranes	1800	67.31424523	20
18	0.0373968029068827 (Lack of Maintenance)	Failure to carry out necessary checks after bad weather conditions	1800	67.31424523	21
19	0.0373968029068827 (Lack of Maintenance)	Not performing required periodic controls	1800	67.31424523	22
22	0.0373968029068827 (Lack of Maintenance)	Failure to periodic controls of the elevator	1800	67.31424523	23
5	0.0358548574518207 (Inadequate Machine Installation-Usage Information)	No grounding	1800	64.53874341	24
16	0.0358548574518207 (Inadequate Machine Installation-Usage Information)	Installation is not done by experts	1800	64.53874341	25
17	0.0358548574518207 (Inadequate Machine Installation-Usage Information)	Failure to take safety measures in crane installation	1800	64.53874341	26
21	0.0358548574518207 (Inadequate Machine Installation-Usage Information)	No grounding	1800	64.53874341	27
6	0.0351001075428182 (Awareness)	Hooks without safety catch	1800	63.18019358	28
23	0.0351001075428182 (Awareness)	No fall protection equipment	1800	63.18019358	29
50	0.0790730405706215 (Design Errors)	Lack of protective covers of moving. dangerous points of the crane	750	59.30478043	30
14	0.0310652239332324 (Elements in the Study Area)	Power cut	1800	55.91740308	31

Table 4. cont.

Ranking with Fine-Kinney	Global (overall) weighted score of sub-criterion (GWS)	Definition of hazard	Fine-Kinney risk score (FRS)	Integrated risk score (IRS) IRS= GWSxFRS	New ranking
55	0.0790730405706215 (Design Errors)	No protective parts in electrical sections	600	47.44382434	32
4	0.0246905456069212 (Insufficiency)	Using cranes by unauthorized workers	1800	44.44298209	33
10	0.0240642253941192 (Experience)	Interference when the crane is in operation	1800	43.31560571	34
35	0.0456945529320244 (Compliance with technology)	Non-measurement of wind speed	900	41.12509764	35
26	0.0431228557110697 (Lack of Maintenance)	Insufficient braking	900	38.81057014	36
13	0.0207751999630086 (Narrowness of the Working Area)	Entering under the load	1800	37.39535993	37
25	0.0373968029068827 (Lack of Maintenance)	No controls of the crane	900	33.65712262	38
42	0.0373968029068827 (Lack of Maintenance)	Failure of chain controls. working with defective chain	900	33.65712262	39
11	0.0177968581680381 (Information on the Study Area - Warning Signs)	Failure to take safety measures in working environment before working with a crane	1800	32.0343447	40
15	0.0177968581680381 (Information on the Study Area - Warning Signs)	Absence of warning signs	1800	32.0343447	41
20	0.0177968581680381 (Information on the Study Area - Warning Signs)	Not covered the area around the elevator	1800	32.0343447	42
28	0.0351001075428182 (Awareness)	Not using safety clamp	900	31.59009679	43
32	0.0351001075428182 (Awareness)	Using more than one crane on the same construction site	900	31.59009679	44
49	0.0351001075428182 (Awareness)	Leaving the used apparatus on the hook	750	26.32508066	45
64	0.0790730405706215 (Design Errors)	The drum does not comply with standards	300	23.72191217	46
65	0.0790730405706215 (Design Errors)	Rope ends are not connected to the drum	300	23.72191217	47
53	0.0373968029068827 (Lack of Maintenance)	Exceeding speed limits on lifting vehicles	600	22.43808174	48
38	0.0246905456069212 (Insufficiency)	Giving bi-directional movement	900	22.22149105	49
56	0.0358548574518207 (Inadequate Machine Installation-Usage Information)	Failure to take measures when tower crane is not in use	600	21.51291447	50
37	0.0207751999630086 (Narrowness of the Working Area)	Lack of sufficient space for Crane installation	900	18.69767997	51
36	0.019208973057785 (Lack of communication)	Miscommunication between maneuverer and operator	900	17.28807575	52
48	0.019208973057785 (Lack of communication)	Lack of appropriate communication equipment	900	17.28807575	53
54	0.0272765637693887 (Financial insufficiency)	Lack of sufficient capacity of the crane	600	16.36593826	54
52	0.0240642253941192 (Experience)	Uneducated slingshot and maneuvering operators	600	14.43853524	55
60	0.0373968029068827 (Lack of Maintenance)	Availability of control panel	300	11.21904087	56
63	0.0373968029068827 (Lack of Maintenance)	Crane derailment	300	11.21904087	57
58	0.0358548574518207 (Inadequate Machine Installation-Usage Information)	Exceeding crane capacity	300	10.75645724	58
59	0.0358548574518207 (Inadequate Machine Installation-Usage Information)	Non-conformance of drum channel to standards	300	10.75645724	59
61	0.0358548574518207 (Inadequate Machine Installation-Usage Information)	Lack of instruction manual	300	10.75645724	60

Table 4. cont.

Ranking with Fine-Kinney	Global (overall) weighted score of sub-criterion (GWS)	Definition of hazard	Fine-Kinney risk score (FRS)	Integrated risk score (IRS) IRS= GWSxFRS	New ranking
67	0.0358548574518207 (Inadequate Machine Installation-Usage Information)	The floor where the elevator is placed does not meet the standards	300	10.75645724	61
68	0.0358548574518207 (Inadequate Machine Installation-Usage Information)	Exceeding elevator capacity	300	10.75645724	62
69	0.0358548574518207 (Inadequate Machine Installation-Usage Information)	The floor where the crane is placed does not meet the standards	300	10.75645724	63
70	0.0358548574518207 (Inadequate Machine Installation-Usage Information)	The control panel is not available and is not available to an authorized person	300	10.75645724	64
51	0.0177968581680381 (Information on the Study Area - Warning Signs)	No safety instructions. no warning signs	600	10.6781149	65
57	0.0177968581680381 (Information on the Study Area - Warning Signs)	No safety instructions. no warning signs	600	10.6781149	66
62	0.0351001075428182 (Awareness)	Lack of sufficient illumination. no visibility	300	10.53003226	67
71	0.0358548574518207 (Inadequate Machine Installation-Usage Information)	The misuse of the crane	200	7.17097149	68
72	0.0358548574518207 (Inadequate Machine Installation-Usage Information)	The misuse of the elevator	200	7.17097149	69
33	0.00774462528474803 (Climatic Effects)	Stormy weather essentials	900	6.970162756	70
34	0.00774462528474803 (Climatic Effects)	Wind speed exceeds working conditions	900	6.970162756	71
66	0.00774462528474803 (Climatic Effects)	Lightning	300	2.323387585	72
73	0.0351001075428182 (Awareness)	Leaving material suspended	50	1.755005377	73

Findings

Integrated risk scores of the Fine-Kinney and AHP methods are presented in Table 4. The table shows the ranking of the scores when multiplied by the global (overall) weights calculated for the sub-criterion with the first risk score calculated with Fine-Kinney. Integrated risk scores were calculated with this formula:

Integrated Risk Score (IRS) = Global (Overall) Weighted Score of Sub-criterion (GWS) × Fine-Kinney Risk Score (FRS)

Significant differences were found between the integrated risk ranking application and the risk ranking calculated by the Fine-Kinney method. For example, according to the Fine-Kinney method, a hazard (Failure to check bolts) in the third rank was increased to the first rank. Similarly, in the Fine-Kinney method, the 24th hazard was placed in the 7th rank (no warning signal in crane movement), the 27th ranked danger ranked 8th (Lack of lighting of the load hook), and the 29th ranked danger ranked 9th (Improper hooks).

On the other hand, in the Fine-Kinney table, the hazard in 5th (No grounding) is placed in 24th rank, the 12th hazard (Not performing the periodic controls of the cranes) is placed 20th, the 6th hazard (Hooks without safety catch) is placed 28th and the 4th hazard (Using cranes by unauthorized workers) is placed 33rd.

However, as seen in the first 6 lines of Table 4, there is no significant difference in both Fine-Kinney rankings and after ranking AHP application for the hazards where very high risk score is calculated. In the case of Fine-Kinney, 3rd hazard was placed in the 1st rank and the 1st hazard was in 2nd place. In the same way, the 2nd hazard in the Kinney method was placed in the third rank, and the 7th rank was in the 4th rank.

The same applies to hazards with low risk scores. For example, hazards such as ‘uneducated slingshot and maneuvering operators’, ‘lack of appropriate communication equipment’, and ‘the inability of the control panel to be used’, have been found to be lower in the Fine-Kinney method and have not been able to up higher risk scores for AHP-determined scores.

The applied method does not increase the insignificant risks to a very high degrees or does not reduce a significant hazard to the low rankings. These results also show us that the applied risk ranking method does not provide manipulative results for high risks which may have really vital consequences.

Another important result we have obtained with this method is that, there may be a risk score difference between the hazards that take the same risk scores with traditional methods. In the Fine-Kinney method, the number of hazards with 1800 risk points is 20, the number of hazards with 900 points is 24, and the number of hazards with 600 points is 7. These hazards in the same risk score were also graded according to the risk score with this method. Thus, the sensitivity of the risk assessment methods and the ability to rate risks have been increased with the method we have applied.

CONCLUSIONS

Lifting vehicles used in construction sites cause many fatal accidents. Within the scope of this study, the Fine-Kinney method was integrated with AHP and a new risk assessment was applied for the lifting vehicles. The risk scores were recalculated and ranked. Thus, the defects of the Fine-Kinney method were desired to be reduced. As a result of the application, the risk scores of many hazard criteria changed and many risks with the same score had different risk scores and the priorities was changed. As a result of the application, the hazards related to machines such as 'design errors', 'failure of periodic controls' and 'lack of maintenance' were found to be more important and priority. 'Behavioral criteria' including personal deficiencies such as 'lack of awareness' and 'inadequacy' were followed by high risk scores. 'Managerial errors' and 'working environment' have also been identified as another important causes of accidents.

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