INFLUENCE FACTOR-BASED RISK ASSESSMENT METHODOLOGY FOR CONSTRUCITON

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ABSTRACT: Many work-related risk factors can cause construction site hazards. Therefore, safety management begins with measuring the magnitude of risk involved in a project. This study proposes a methodology for risk assessment of major trades at a particular construction site. To assess risk, this methodology integrates hazard severity and frequency, and their magnitude is calculated based on actual work-site hazards.

This methodology also considers the influence factors that affect the frequency of work-related hazards. To select the appropriate influence factors, a two step approach is deployed. First, the predominant factors are identified through a literature review. Second, a selective process filters out the influence factors that are difficult to analyze quantitatively, and these extracted factors are weighted using expert surveys. Finally, the factors are combined and a quantitative risk assessment methodology is proposed.

Keywords: Risk management, Risk assessment ,Influence Risk Factor

1. INTRODUCTION

The risk has increased in construction industry because construction has characteristics which are complicated and large-sized tendency, high mobility of workers.

The Korea Occupational Safety and Health Agency (KOSHA) for 2007 indicate that the second highest number of injuries and fatalities among all of industries occurred in construction.

The one of construction industry's characteristic is that similar hazards are happened over and over again. So safety managers make an effort to prevent hazards, but that got little effectiveness. This result showed that safety management didn't succeed.

Risk management consists of four interdependent component: hazard identification, risk analysis, risk control selection, risk control implementation, and maintenance(Chua and Goh 2004). Hazard identification and risk controls are performed well based on many hazard cases and experienced knowledge. But magnitude of risk which is inherently included in risk factor is calculated by qualitative standard and performed perfunctorily. Thus that leads to ineffectiveness of safety management and difficulties for prevention.

To prepare proper risk prevention method, magnitude of risk is measured to be accurate.

Construction hazard is the event that is caused by the interrelation of risk factors : outside work, various work environments, worker characteristic, type of work, equipment, etc. Therefore it has been preceded that to know the kinds of influence risk factors and magnitude of risk influenced factor for risk assessment.

There are many definitions about risk, hazard, risk assessment. In the context of Occupational Safety and Health Administration (OSHA), risk can be defined as integration both the likelihood and the consequences of the hazards. Jannadi and Almishari (2003) also defined risk as a measure of the probability, severity, and exposure of all the hazards of an activity. Baradan and Usmen (2006) defined hazard as the potential for an activity or condition to produce harmful effects. Risk assessment is usually defined a technique that estimates risk to personnel and property impacted upon by a project.

In this paper, three terms are following:

- Risk is a combining frequency and severity of undesirable event.
- Hazard is defined as an inherent characteristic of an activity or situation that has potential of causing undesirable event that have injuries and fatalities.
- Risk assessment can be defined as to know how large magnitude of risk is.

This paper presents a risk assessment methodology considering influence risk factor in construction sites. Developing this methodology is performed by four steps. As a first steps, 10 influence risk factors were extracted by literature reviews and surveys. The second step was based on the first, that the results for 10 influence risk factor were weighted by Analytic Hierarchy Process (AHP). The third step was assessing the risk of trades. It was based on accident cases including 536 injuries and 76 fatalities cases. Final step was integrating weight of influence risk factors and risk of trades. The objective , scope and research process appear in Fig.1.

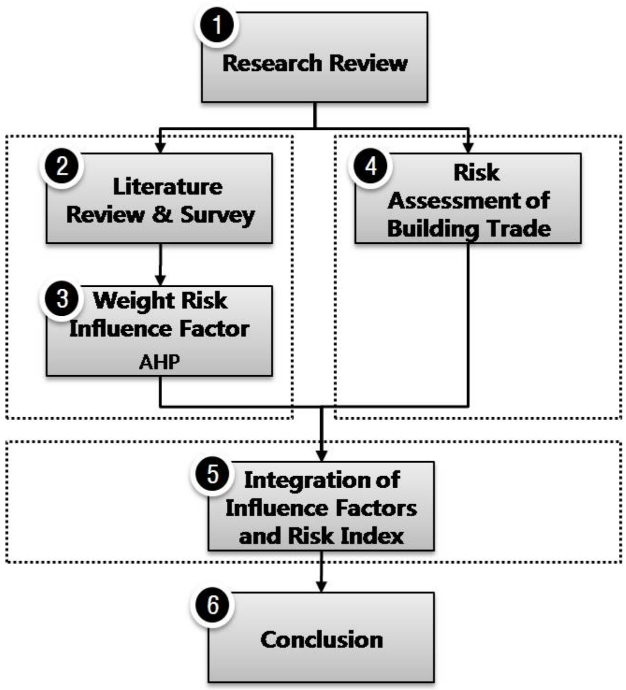

Fig.1 Research Process

2. Preliminary Study

2.1 Literature Review

There were many studies about risk assessment. Yu Sun et al (2008) suggested how to determine priority of risk. They used risk importance evaluation index to calculate the priority. Baradan and Usmen (2006) conducted quantitative effort on cost of lost time and median number of days away from work. And they introduced formula about risk score that combined nonfatal injuries and fatalities. Chua and Goh (2004) suggested that probabilities of occurrence for each event can be based on subjective sources such as expert judgment or objective observations of accident cases. Jannadi and Almishari (2003) provided a risk assessor model using two equations calculating risk. Seo and Choi (2008) classified frequency and severity by three steps to use risk assessment matrix.

2.2 Risk Assessment Method

Risk assessment matrix has commonly been used in evaluating risk. It provides classification for frequency and severity. Frequency is classified as frequent, probable, occasional, remote, improbable (MIL-STD-882B 1977). Severity is characterized as catastrophic, critical and negligible (MIL-STD-882B 1977).

Concept of risk assessment matrix is used in OSHA, KOSHA and MIL-STD-882B etc. As shown in Table. 1, there are three risk assessment method.

Table. 1 Risk Assessment Methods

	KOSHA	MIL-STD-882B	Corpor.A
Frequency	5steps (frequent, probable, occasional, remote, improbable)	5steps (frequent, probable, occasional, remote, improbable)	3steps (high, medium, low)
Severity	4 steps (fatal disaster, slight day off disaster, slight non-day off disaster, negligible)	4 steps (fatal disaster, slight day off disaster, slight non-day off disaster, negligible)	3steps (high, medium, low)
Magnitude of risk	20steps (1~20steps)	4step (acceptable, acceptable under control, undesirable, unacceptable)	5steps (Very high, high, medium, low, very low)
Scope	All industry	All industry	Construction site

KOSHA's method can be applied to all the industries. But the method can't reflect construction characteristic. And standards of classification which consist of textual oriented and qualitative evaluations are difficult to assess risk of building trades.

Although MIL-STD-882B which is safety program of Department of Defense suggests a quantitative standard of frequency and severity, that has some limitations for clearance of standard. Also the standard reflects and includes characteristic of construction site to assess risk effectively.

Risk assessment of corporation A reflect characteristic of construction, but risk is assessed separately by work activity, type of building, work condition. So corporation A's method has limitations for integration of all the risk influence factors. Risk assessment is the process of risk of trades is assessed by experiential judgment of safety managers.

With the exception of corporation A's method, the standards should be defined to be applied to construction site directly. In order to redefine the standard, it is necessary to including expert suggestion and accident cases occurred in construction sites. Thus this study suggests quantitative risk assessment model to make up for the limitations.

3. Influence Risk Factor

3.1 Extract Risk Factor

Several studies have been made on factor causing accident or disaster. Cause of accident is unsafe acts of persons and unsafe mechanical or physical conditions

(Heinrich 1950). And Suraji et al (2001) selected inappropriate act, unstable condition, personal factor for direct causes of accidents.

For the causes of accident mentioned above, the causes can be characterized as work, worker, work condition.

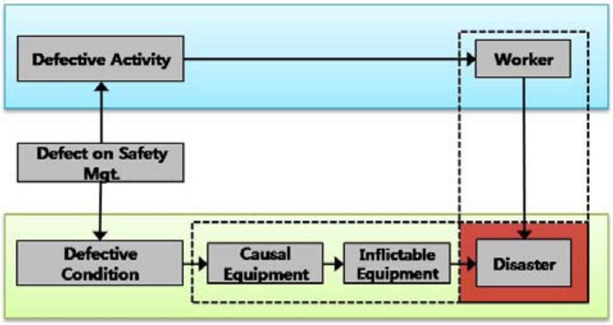

Fig. 2 Cause of Accident

To occur an accident consists of interrelated factors. So, safety managers consider many factors for prevention of accidents. One event is caused by factors have interrelationship. But considering acquirable data and safety manager's capability, influence risk factors are extracted. The extracting process are follow as Fig. 3

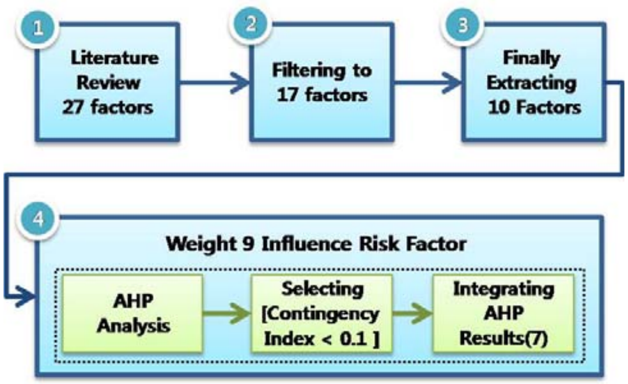

Fig. 3 Weight Factors Process

Literature reviews are preceded to extract influence risk factors. Many studies have been made on finding factors which influence risk. 27 factors are extracted from KOSHA (1997), Ko et al (2005), Carter and Smith (2006), Sun et al (2008), Seo and Choi (2008), etc. After extracting 27 factors, 10 factors are filtered off by measurable and statistical data.

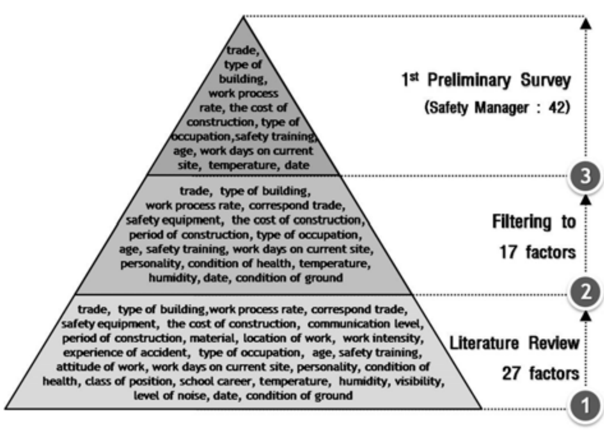

Fig. 3 Extracting Factors

After that, preliminary surveys are performed by 42 safety managers based on remained 17factors. The survey demands that 42 safety managers select priority of influence risk factors. The process of extracting factors appears in Fig. 4.

3.2 Weight Influence Risk Factor

Analytic Hierarchy Process (AHP) is used to weight influence risk factor. AHP is a structured technique for handling with complex decisions. But in this study, AHP is only used to weight factors. 9 factors are surveyed by pairwise comparison. The reason for using 9 factors is that safety management of construction site is performed by trade and accident cases are summarized by trade. So 9 factors and risk per trade are integrated and then, they are used to assessing risk considering construction site characteristic.

7 surveys of 13 collected surveys their contingency indexes are lower than 0.1 are analyzed. 7 surveys are analyzed separately, and the weights are calculated by geometric average.

Table. 2 Result of AHP

	(f1)	(f2)	(f3)	(f4)	(f5)	(f6)	(f7)	(f8)	(f9)
(f1)	1.000	1.952	1.292	1.842	1.511	1.258	0.960	3.524	2.479
(f2)	0.512	1.000	0.869	1.292	0.944	1.000	0.689	1.768	1.575
(f3)	0.774	1.150	1.000	2.034	1.042	1.042	0.635	2.420	1.952
(f4)	0.543	0.774	0.492	1.000	0.662	0.635	0.445	1.486	1.219
(f5)	0.662	1.060	0.960	1.511	1.000	1.000	0.624	2.000	2.065
(f6)	0.795	1.000	0.960	1.575	1.000	1.000	0.635	2.627	2.155
(f7)	1.042	1.450	1.575	2.246	1.601	1.575	1.000	2.918	2.380
(f8)	0.284	0.566	0.413	0.673	0.500	0.381	0.343	1.000	1.000
(f9)	0.403	0.635	0.512	0.820	0.484	0.464	0.420	1.000	1.000
Avg.	0.167	0.104	0.126	0.077	0.115	0.122	0.172	0.054	0.062

where: (f1): work process rate, (f2): the cost of construction, (f3): type of building, (f4) age, (f5): type of occupation (f6) work days on current site, (f7): safety training, (f8): date, (f9): temperature,

As the table 2. Indicates, weight of work process rate and safety training are relatively higher values than other factors. Work process rate is 0.167 and safety training is 0.172. And contingency index is 0.0049 which can be said that respondents are consistent and reliable.

3.2 Classifications of Risk Factors

To arrange detailed classification of 9 factors mentioned above, KOSHA's industry disaster investigation of code standard and expert suggestion are used. But detailed classification of safety don't present on construction accident case and type of safety training varies from every construction site. So detailed classification of safety training is characterized by frequency of safety training.

Number of accidents, non-fatalities injuries, fatalities and commitment of worker etc. are considered in calculating process of risk of classifications. Formula 1 summarizes the calculating process of risk classifications mentioned above.

Risk of classification = (DAN + DAF) / (NA · CW) (1)

where: DAN: number of days away from work by non-fatal injuries, DAF: number of days away from work by fatalities , NA: Number of accidents, CW : commitment of work.

And site weights are assessed by ration of average of risk of classifications and risk of classifications. The reason for introducing site weight is that numbers of classification of factor are different from each others. The detailed classifications by factors are represented in Table 3.

Table. 3 Classification of Factors

Factors													
(f_1)	definition	ratio of work process											
	classification(%)	~10	11~20	21~30	31~40	41~50	51~60	61~70	71~80	81~90	91~100		
	risk of classification	0.083	0.092	0.124	0.111	0.085	0.099	0.111	0.088	0.107	0.100		
	site weight	0.830	0.920	1.240	1.110	0.850	0.990	1.110	0.880	1.070	1.000		
(f_2)	definition	cost of construction project											
	classification (billion dollars)	~5	5~10	10~30	30~50	50~100	100~500	500~1000	1000~				
	risk of classification	0.139	0.174	0.132	0.143	0.116	0.084	0.114	0.098				
	site weight	1.112	1.392	1.056	1.144	0.928	0.672	0.912	0.784				
(f_3)	definition	type of building											
	classification	Social sports facilities	Housing accommodation	Hospital and school facilities	Apartment	Commercial public facilities							
	risk of classification	0.220	0.159	0.174	0.216	0.231							
	site weight	1.100	0.795	0.870	1.080	1.155							
(f_4)	definition	number of years since born											
	classification	twenty	thirties	forties	fifties	sixties							
	risk of classification	0.061	0.197	0.208	0.270	0.264							
	site weight	0.305	0.985	1.04	1.35	1.32							
(f_5)	definition	type of occupation											
	site weight	2.504	2.403	2.012	2.503	2.466	1.170	1.077	0.753	0.671			
	classification	Bric worker	Sheetmetal worker	Common worker	Watertight worker	Re-bar worker	Plumber worker	Tile worker	Concrete Finish worker	Earth			
	risk of classification	0.030	0.029	0.015	0.018	0.011	0.007	0.006	0.005	0.014			
	site weight	0.536	0.516	0.265	0.332	0.201	0.117	0.115	0.098	0.259			
(f_6)	definition	the days of working in current site											
	classification	~10days	10~20days	20~30days	1~2month	2~3month	3~4month	4~5month	5~6month	6~12month	1year~		
	risk of classification	0.242	0.199	0.147	0.125	0.097	0.068	0.052	0.038	0.021	0.011		
	site weight	2.42	1.99	1.47	1.25	0.97	0.68	0.52	0.38	0.21	0.11		
(f_7)	definition	the number of safety training in three month											
	classification	0	1	2	3~4	5~6	7~8	9~10	11~15	16~20	21~		
	risk of classification	0.327	0.232	0.158	0.092	0.053	0.045	0.037	0.026	0.018	0.012		
	site weight	3.27	2.32	1.58	0.92	0.53	0.45	0.37	0.26	0.18	0.12		
(f_8)	definition	correspond date for site											
	classification (month)	1	2	3	4	5	6	7	8	9	10	11	12
	risk of classification	0.068	0.086	0.173	0.068	0.080	0.086	0.080	0.111	0.049	0.086	0.056	0.056
	site weight	0.82	1.03	2.08	0.82	0.96	1.03	0.96	1.33	0.59	1.03	0.67	0.67
(f_9)	definition	temperature of site											
	classification(℃)	~0	0~4	4~8	8~12	12~16	16~20	20~24	24~28	28~			
	risk of classification	0.196	0.163	0.109	0.082	0.054	0.043	0.101	0.125	0.128			
	site weight	1.76	1.47	0.98	0.74	0.49	0.39	0.91	1.12	1.15			

4. Risk Assessment by Trades

4.1 Risk Assessment Method and DATA

Risk assessment in this study is taken to perform based on 3 steps. First step is assessing severity of risk. Second step is assessing frequency of risk. Final step that is based on first and second step is integrating severity and frequency.

The data for assessing risk is collected from 4 general contractors those gave accident cases over 5years (2003~2007). The number of cases is 596. And non-fatalities are 536, fatalities are 76.

The trades which are used in Korea are classified by 22. The landscape architecture, Ondol and special building trades are excluded. The reason for excluding above trades is that accident cases are very little and Ondol trade is applied in only Korea.

4.2 Assess Severity and Frequency

There are measuring indexes that are loss days and insurance fee (Knab 1978). Considering various distribution of construction site, type of occupation and wage, insurance fee has large distribution. So severity of risk is assessed based on loss days.

Loss days are the value which includes both non-fatal injuries and fatalities of days away from work. According to investigation standard of Korea, loss days are prescribed by not confirmed value but range of days. Thus severity of risk is determined by dividing the amount of loss days by number of accident case given trade.

$$\text{Severity} = \text{Amount of Loss Days} / \text{Number of accident case given trade} \qquad (2)$$

Table. 4 Result of Risk Assessment by Trade

	No. Accident	No. Injuries	No. Fatalities	Loss days of Injuries	Loss days of Fatalities	Severity	Frequency	Relative Severity	Relative Frequency	Ratio. Commitment of worker given trade	Risk given trade
Roof Work	`	8	4	2185	9000	932.08	3.661	73.34	100.00	0.55	85.64
E/V Work	5	3	2	354.5	6000	1270.90	2.622	100.00	71.61	0.32	84.63
Curtain wall Work	8	5	3	996.5	5250	780.81	1.579	61.44	43.14	0.85	51.48
R/C Work	235	229	26	11053	88500	423.63	2.782	33.33	75.99	15.38	50.33
Steel structure Work	39	30	9	998	29250	775.59	0.871	61.03	23.80	7.51	38.11
Wall	42	35	5	872.5	14250	360.06	1.392	28.33	38.04	4.82	32.83
Foundation Work	37	28	7	1064	21000	596.32	0.811	46.92	22.16	7.24	32.24
Plastering Work	39	31	4	3205.5	9000	312.96	1.335	24.63	36.46	4.40	29.96
Temporary Work	33	29	4	3475.5	7500	332.59	0.845	26.17	23.09	6.55	24.58
Watertight Work	15	17	1	243	2250	166.20	1.248	13.08	34.09	2.42	21.11
Dismantling Work	19	18	1	2841	750	189.00	0.993	14.87	27.13	3.21	20.09
Painting Work	12	11	1	310.5	3750	338.38	0.491	26.62	13.41	4.10	18.90
Earth Work	16	14	3	210	6750	435.00	0.371	34.23	10.13	7.69	18.62
Tile Work	5	4	1	187.5	2250	487.50	0.315	38.36	8.62	2.66	18.18
Etc. Work	22	20	2	550	6000	297.73	0.485	23.43	13.25	7.61	17.62
Brick Work	9	8	1	85	2250	259.44	0.392	20.41	10.71	3.85	14.79
Stone Work	12	11	1	157.5	750	75.63	0.941	5.95	25.70	2.14	12.37
Window & Door Work	5	4	1	300	750	210.00	0.236	16.52	6.44	3.56	10.31
Metal Work	8	8	0	649	0	81.13	0.418	6.38	11.42	3.21	8.54
Finish Work	9	9	0	642	0	71.33	0.294	5.61	8.03	5.14	6.71
Isolation Work	7	7	0	88.5	0	12.64	0.918	0.99	25.07	1.28	4.99
Wood Work	7	7	0	131	0	18.71	0.442	1.47	12.06	2.66	4.21
Total	596	536	76	30599.5	203250					Avg. Risk by trade	27.47

Determining frequency of risk given trade can be represented as dividing number of accident given trade by multiple total number of accident cases and ratio of commitment of worker given trade.

Frequency = Number of accident cases / (Total number of accident cases * ratio of commitment of worker given trade) (3)

4.3 Integrating Severity and Frequency

The process of conversion is needed to integrate two indexes which are mentioned above. To convert indexes, relative severity index and relative frequency index are introduced. The largest value is converted to 100. Then other values can be represented as ratio of that. Relative indexes are calculated separately by both severity and frequency. After that relative risk is determined by geometric mean of relative severity and frequency. The process and results are summarized in table 4.

5. Assessing Site Risk

Formula 4 show the method for integrating weight of influence risk factor and risk given trades. Site risk is determined by multiplying site weight and influence risk factor weight analyzed by AHP.

$$R_S = R_R \sum_{i=1}^{9} (f_{iw} \times f_{is}) \qquad (4)$$

This formula can be applied to develop risk assessment program. Safety manager inputs data about characteristics of site. Then Weight module and risk assessing module calculate the site risk. The process mentioned above is represent in fig. 4.

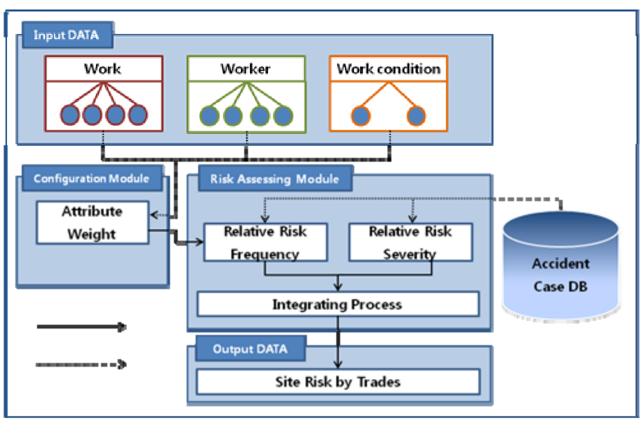

Fig 4.

6. Conclusion

Construction project has changeable risk factors from work condition, characteristics of worker, temperature, trade etc.

This study is performed to suggest risk assessment methodology considering characteristic of construction site. Suggesting methodology, 10 influence risk factors are extracted from literature review and expert survey. And relative risk which is only focused on trade is proposed is calculated.

Finally, risk assessment methodology considering characteristics of construction site is suggested by integrating influence risk factors and relative risks.

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