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Risk Assessment of Common Construction Hazards among Different Countries

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Abstract

The construction industry has the largest number of injuries compared to other industries. Thus, reducing accidents and determining construction risks are extremely important. One of the essential steps for construction safety management is hazard identification, since the most unmanageable risks are from unidentified hazards. This paper aims to rank the risk of construction hazards. To achieve this aim, the frequency and severity of accidents from the most common hazards at construction sites, were assessed. The data for this study were collected using a web survey. The questionnaire was sent to 300 safety professionals including safety managers, safety officers, and safety experts who were randomly selected from 20 countries. Of those, 76 completed responses were returned. The results reveal that there is no significant difference in severity and frequency of accidents between the studied countries. It was also found that a lack of safety-forward attitudes, a lack of awareness of safety regulations, poor safety awareness of project managers, and a lack of knowledge are the hazards with the most risk in construction projects. The outcome of this study can help organizations and managers prepare proper safety plans and also to increase the knowledge of partners in construction sites through training and awareness programs.

Keywords

Risk Assessment, Frequency and Severity, Construction Hazard, Construction Safety

1. Introduction

Construction is often the largest employer in any country (Bust et al., 2008). It has been well documented that a large number of accidents occur in the construction industry (Bust et al., 2008 ; Camino et al., 2008; Gregory and Simon, 2006; Wang et al., 2006). In modern society, the construction industry has been defined as a dangerous profession (Liao and Perng, 2008; Niza et al., 2008).In Korea, the construction industry included less than10% of gross domestic product in 2007, while its occupational fatalities accounted for 20% of total fatalities (Kim et al., 2010). In Taiwan, occupational fatalities accounted for0.29 deaths per thousand construction employees in 2005, which was much higher than the fatality rate for all industries (Cheng et al., 2010). In Hong Kong, the construction accident rate was approximately 68.1 per 1000 workers which is higher when compared to other industries (Ling et al., 2008).

It is commonly known that accidents have serious impacts on the construction industry both in financial and humanitarian terms (Dorji and Bonaventura H.W., 2006) such as “wasting cost”, “reducing productivity”, “decreasing renown of company”, and “establishing negative psychological impact on workers” (Mohamed, 1999; Tam et al., 2004).Yi and Langford (2006) declared that hazardous situations cause wasted time and increased the cost of projects. However, excessive or unnecessary safety measures may also result in both delays in schedule and in additional costs (Yi and Langford, 2006).Thus, the managers, as key project members, should assess the most hazardous and risky conditions in order to mitigate accidents, optimize cost and time, and promote quality of production.

To manage and control construction hazards, the prevention of hazardous events and the possibility of limiting the severity of occurred hazards should be considered (Gregory and Simon, 2006). Thus, probability and severity of construction hazards, as two fundamental elements of risk management (Garvey Paul, 2009), are to be assessed. Although, extensive research has been conducted to find the causes and effects of construction hazard occurrence, the lack of a comprehensive study to rank the common construction hazards between various countries has not been undertaken. This study aimed at prioritizing the most common construction hazards, in order of their risks, in different countries by investigating the frequency and consequences of occurrence. By doing so, it is expected that the most critical hazards highlighted will increase construction participant awareness in order to reduce accident rates.

2. Critical Causes of Accidents on the Construction Site

There are several factors that cause accidents on construction sites. Tam et al. (2004) found that the main factors affecting safety performance in China are managers’ poor safety awareness, lack of training, reluctance to commit resources to safety, and reckless operations. The results of their investigation are summarized as follows:

- Large numbers of contractors do not have a documented safety management system or safety manuals,
- Only a few contractors provide necessary personal protection equipment for workers,
- Top managers are reluctant to attend safety meetings, and
- Most contractors are reckless about safety training.

Lubega et al. (2000) found that the causes of construction accidents in Uganda include a lack of knowledge about safety rules, engaging an inexperienced workforce, and poor respect for safety. Furthermore, Dejus (2007) conducted a study in the Lithuanian Republic and identified that the the most reasons of serious and mortal accidents are due to inexperienced employees, lack of qualifications and understanding risk in a construction site. In adition, Irizarry and Abraham (2006) defined that lack of awarness of the dangers, lack of safe behaviour, and lack of safety training as the factors which could influence the risk perception of ironworkers in United States. Abdul Rahim et al. (2008) carried out a survey in Malaysia for identifying causes of accidents in construction sites. They found that unsafe methods, including incorrect procedures, knowledge level, and disobedience of procedures are the most frequent reasons for accidents in construction sites.

A review of the literature reveals that causes of construction accidents are classified into the most influential factors such as job site conditions; equipments and materials; human; and management factors (Pipitsupaphol and Watanabe, 2000). The job site conditions include nature and physical layout of the work location and the status of tools (Abdelhamid and Everett, 2001). Any equipment and material which in violation of contemporary safety standards might cause accidents to occurr (Abdelhamid and Everett, 2001). Human error has been known as ‘‘any one set of human actions that exceed some limit of acceptability’’ (Rigby, 1970) including overloading of human competences (both psychological and physical) (Abdelhamid and Everett, 2001). Management is also considered as a factor contributing to accidents, i.e. failing to provide adequate essential tools due to lack of knowledge and awareness. Table 1 presents a holistic outline of existing causes of accidents and hazards in construction sites as found in the literature (Abdul Rahim et al., 2008; Gervais, 2003; Heinrich, 1980; Hinze, 1981; Hinze and Raboud, 1988; Kartam and Bouz, 1998 ; Lubega et al., 2000; Pipitsupaphol and Watanabe, 2000; Tam and Fung, 1998; Tam et al., 2004).

Table 1: A Holistic Outline of the Critical Hazards and Causes of Accidents in Construction Sites

Human	Management	Job Site Conditions	Equipment & Material
-Lack of certain abilities -Lack of certain attitudes such as stubbornness or recklessness -Physical and emotional stress -Excessive overtime work for labor -Reluctance to input tools for safety -Misplacing objects -Overexertion or strenuous movement -Struck by falling objects, materials and tools -Loss of balance -Stepping on or striking against objects -Inappropriate use of ladders and hoists -Improper cleaning and unusable materials -Lack of teamwork spirits -Transient workforce -Dangerous demolition work	-Lack of certain knowledge -Lack of awareness of safety regulations -Inadequate safety performance -Supervisory fault -Lack of experienced project managers -Poor inspection program -Poor safety awareness of project managers -Lack of innovative technology -Substandard structure / parts of structure	-Excessive Noise -Slippery and muddy work surface -Poor ventilation -Poor illumination -Lack of edge protection -Hole and edge -Limitation of working area -Collapse of temporary structure	-Operating equipment without authority -Using defective tools or equipment -Mechanical failure of machinery -Unsafe facilities and equipment -Low tool maintenance -Lack of protection in material transportation -Lack of protection in material storage -Failure to secure materials during hauling/ lifting -Lack of warning system

3. Risk Assessment Analysis

In the context of projects, risk is an event that, if it occurs, adversely affects the achievement of the project objectives (Carter, 2006). Determining the risk rate of construction hazards depends on the probability and severity of accident occurrence (Carter, 2006).Probability or frequency is defined as the likelihood of a hazard's potential being realized and initiating an incident or series of incidents that could result in harm or damage. Severity of consequences is defined as the extent of harm or damage that could result from a hazard-related incident (Manuele, 2006). Figure 1 illustrates the risk level assessment procedure of this study.

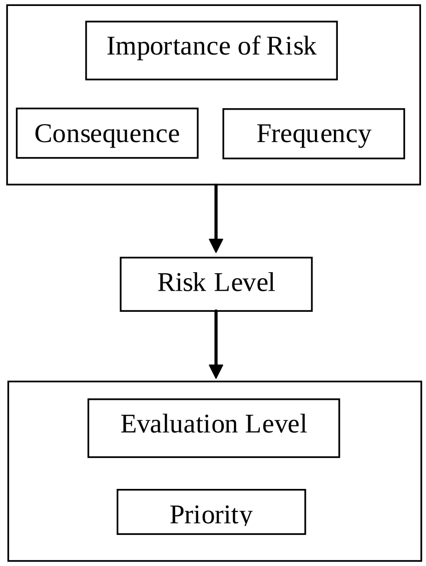

Figure 1: Safety Impact Assessment Procedure

Risk management comprises four interdependent elements: (1) hazard identification; (2) risk analysis; (3) risk control selection; and (4) risk control implementation and maintenance (Chua and Goh, 2005). Risk can be assessed and presented using matrices by estimating probabilities and consequences in a qualitative manner or with quantitative values (Ayyub, 2003).

To rank various risks in order of importance, a risk matrix has been used (Jeong et al., 2010). A risk matrix is a table that includes several categories of “probability”, “frequency”, or “likelihood” for its rows (or columns) and several categories of “severity”, “consequences”, or “impact” for its columns (or rows) as shown in table 2 (Anthony Cox, 2008).Table 2 also demonstrates that risk will increase if probability or severity rises or both rise concurrently. A risk matrix might be used as a 3×3 cell matrix, 5×5 cell matrix, and even 7×7 cell matrix for risk assessment of a larger structure (Jeong et al., 2010). This study follows a 5×5 cell risk matrix, meaning five different levels of frequency and severity.

Table 2: Risk Matrix of Construction Hazards

Level of Consequence	Description
1	Insignificant
2	Minor
3	Moderate
4	Major
5	Catastrophic

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Level of Frequency	Description
1	Rare
2	Unlikely
3	Possible
4	Likely
5	Almost Certain

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Probability					
5	5	10	15	20	25
4	4	8	12	16	20
3	3	6	9	12	15
2	2	4	6	8	10
1	1	2	3	4	5
	1	2	3	4	5
	Consequence				

4. Research Methodology

The data used in this study was collected through a questionnaire survey. The questionnaire was conducted to investigate the frequency and severity of common construction hazards on construction sites. The design of the questionnaire was based on Fan and Yan (2010). Thus, in the first stage of survey design, length, format, and the order of the questions were investigated and optimized using a pilot survey with a small group of respondents. The electronic form of the survey was sent to six safety experts in May 2010 to assure that the final survey fulfilled the objectives of the study. In the second stage, some of the web survey delivery factors such as contact delivery modes, invitation design, and sending reminders were decided upon. In the third stage, comfortableness of completing the questionnaire was considered using multiple-choice and Likert scale questions (see table 3). Moreover, for ease of use, the questionnaire was structured into two main sections. Section A covered the background and general information of respondents, while Section B was divided into two parts, seeking the frequency and severity of hazards on construction sites. In the fourth stage, a free web based software was selected which was easy to use. Finally, the method of cluster sampling was selected for distributing the questionnaire. The questionnaire was sent to 300 safety managers, safety experts, and safety officers who were randomly selected among seven developed countries and 13 developing countries through professional networks from May to August 2010. The experts were requested to fill out the questionnaire and rate the frequency and severity of each safety risk hazard based on their knowledge and experience.

Table 3: The Likert Scale Used to Determine the Level of Frequency and Severity

Scale	Severity	Description	Frequency
1	Insignificant	First aid injuries only and/or minimal impact	Never
2	Minor	Minor injuries and/or short-term impact	Unlikely
3	Moderate	Serious injuries and/or significant impact	Possible
4	Major	Fatalities and/or major short-term impact	Likely
5	Catastrophic	Large number of fatalities and/or major long-term impact	Always

5. Analysis and Results

The survey received 76 complete replies, representing a response rate of 25%. Shin and Fan (2009) conducted a study on survey's response rate by reviewing 35 papers. It was reported that minimum and maximum response rate for web surveys were 5% and 85% respectively, while the mean score of response rate was 0.33 (33%) with the standard deviation of 0.22 (22%). Thus, the obtained response rate of this study is acceptable.

5.1 Respondents' profile

A total of 76 safety professionals, from 15 countries, attended the survey with an equal proportion of developing (50%, n=76) and developed (50%, n=76) countries (see Figure 2).

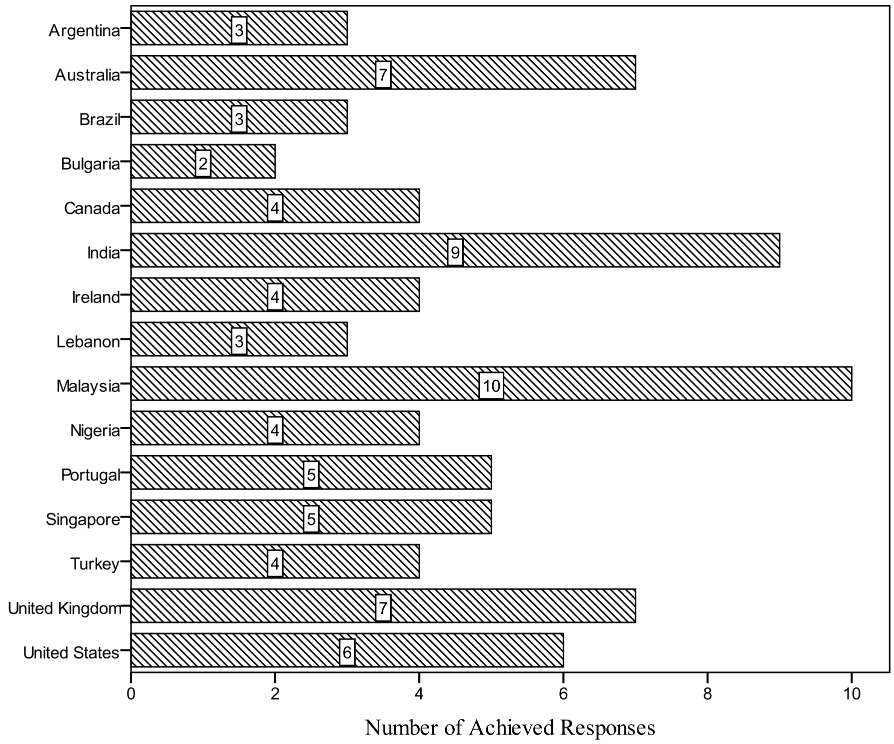

Figure 2: Achieved Responses from Different Countries

Only 14% of the respondents had less than five years of experience while about 60% had more than 10 years of experience. Almost20% of respondents had less than 50 employees in their projects, 15% had between 50 and 250 workers, and about 65% engaged more than 250 employees. Annual revenue of 36% of the respondents' companies was less than 50 million USD. Similarly, 25% of companies earned between 50 and 500 million USD, and about 40% of the companies obtained more than 500 million USD.

The reliability of the Likert scale was tested using Cronbach's alpha coefficient. According to Pallant (2001), a coefficient of more than 0.7 would be considered a reliable scale. The obtained alpha score is 0.966, indicating highly interrelated data and the consistency of the scale with the sample size.

AKruskal-Wallis test was conducted, seeking any significant difference in frequency and severity of construction hazards among the countries of respondents. If the sample sizes are too small, the results of the test should be used with caution (McDonald, 2009) and the results would have less power. Thus, the countries with a sample size of more than five were selected. The test indicated that there is no significant difference in the distribution of severity and frequency of hazards among Malaysia, India, United Kingdom, Australia, and United States ($\chi 2$ (max) = 9.393, ρ (min) = 0.052).

A two sample t-test and Levene's test were performed to investigate the difference in severity and frequency of construction hazards between developing and developed countries. It was found that, apart from the frequency of poor illumination (ρ=0.008), poor ventilation (ρ=0.025), lack of protection in material storage (ρ=0.049), and misplacing objects (ρ=0.007), there is no significant difference in frequency and severity of construction hazards (ρ>0.05) between developing and developed countries.

Above results indicate that the collected data do not depend on the location of the respondents and the data can safely be used in hazard assessment.

5.2 Safety Risk Assessment

By investigating literature, it was realized that risk value is calculated by multiplying accident frequency and consequences (see Equ.1) (Baradan, 2006). The outcome matrix will enable us to discern probable safety risks for each critical hazard in construction projects. The methodology evaluates the significance of the rating of risks in construction projects as follows:

$$R = F \times S \quad \text{Equ.1}$$

where R denotes the significance rating of a safety risk in a construction project; F is the frequency of occurrence (Likelihood of a hazard); and S is the severity of the consequences in terms of injuries (consequence of a hazard).

Table 4 reveals the rate of frequency and severity as well as the risk in order of priority. Based on the results, the most critical hazards in construction projects are lack of certain attitudes (stubborn, recklessness), lack of awareness of safety regulations, poor safety awareness of the project manager, and lack of knowledge. On the contrary, the least critical hazards in construction projects are lack of protection in material storage, lack of innovative technology, lack of protection in material transportation, and misplacing objects.

Table 4: Evaluation of Risks related to Causes of Construction Accidents

Hazards	FOCa	SD.b (FOC)	SEVc	SD. (SEV)	Risk Level	Priority
Lack of certain Attitudes (stubborn, recklessness)	3.11	1.07	3.43	1.07	10.65	Priority 1
Lack of Awareness of Safety Regulations	2.88	0.94	3.60	1.00	10.37	Priority 2
Poor Safety Awareness of Project Manager	2.78	1.19	3.61	1.16	10.05	Priority 3
Lack of Knowledge	2.99	0.92	3.33	0.96	9.94	Priority 4
Inappropriate use of Ladders and Hoists	2.68	1.24	3.67	1.18	9.82	Priority 5
Lack of Experienced Project Managers	2.58	1.21	3.80	1.11	9.80	Priority 6
Dangerous Demolition Work	2.58	1.20	3.71	1.34	9.57	Priority 7
Inadequate Safety Performance	2.83	1.10	3.27	0.96	9.25	Priority 8
Struck by Falling Objects, Materials and Tools	2.59	1.03	3.54	1.12	9.15	Priority 9
Lack of Edge Protection	2.45	1.08	3.72	1.20	9.13	Priority 10
Unsafe Position or Posture	2.79	1.04	3.28	0.95	9.13	Priority 10
Poor Inspection	2.60	1.22	3.50	1.13	9.10	Priority 11
Supervisory Fault	2.59	1.09	3.51	1.22	9.09	Priority 12
Failure to Secure Materials during Hauling or Lifting	2.48	1.08	3.54	1.21	8.78	Priority 13
Reluctance to Input Tools for Safety	2.61	0.89	3.36	0.98	8.76	Priority 14
Stepping or Striking against Objects	2.59	0.99	3.37	0.98	8.72	Priority 15
Physical and Emotional Stress	2.72	0.97	3.17	1.01	8.63	Priority 16

Slippery and Muddy Work Surface	2.59	1.10	3.33	0.85	8.61	Priority 17
Overexertion or Strenuous Movement	2.71	0.72	3.16	0.86	8.55	Priority 18
Excessive Overtime Work	2.76	1.03	3.09	0.93	8.51	Priority19
Hole and Edge	2.52	0.88	3.30	1.12	8.32	Priority 20
Used Defective Tools or Equipments	2.46	0.95	3.38	1.14	8.31	Priority 21
Height	2.08	1.19	3.99	1.30	8.29	Priority 22
Lack of Warning System	2.41	1.13	3.38	1.18	8.15	Priority 23
Operating Equipment Without Authority	2.33	1.06	3.47	1.16	8.10	Priority 24
Transient Work Force	2.74	0.91	2.96	1.04	8.09	Priority 25
Excessive Noise	2.71	1.06	2.97	1.06	8.06	Priority 26
Poor Illumination	2.45	1.02	3.23	1.04	7.90	Priority 27
Unsafe Facilities and Equipments	2.28	1.03	3.44	1.02	7.86	Priority 28
Mechanical Failure of Machinery	2.31	0.92	3.39	1.16	7.82	Priority29
Lack of Certain abilities	2.52	0.79	3.00	0.87	7.56	Priority 30
Limitation of Working Area	2.51	0.91	3.01	1.01	7.56	Priority 30
Lose of Balance	2.24	0.94	3.26	1.17	7.30	Priority 31
Substandard Structure or parts of Structure	2.19	1.02	3.29	1.14	7.20	Priority 32
Poor ventilation	2.20	1.10	3.24	1.08	7.14	Priority 33
Collapse of Temporary Structure	1.96	1.00	3.64	1.42	7.13	Priority34
Lack of Teamwork Spirits	2.37	1.08	2.97	1.04	7.05	Priority 35
Low Tool Maintenance	2.27	1.00	3.06	0.98	6.93	Priority 36
Improper Cleaning and Unusable Materials	2.41	1.01	2.79	1.03	6.72	Priority 37
Lack of Protection in Material Storage	2.28	0.91	2.93	0.98	6.69	Priority 38
Lack of Innovative Technology	2.35	1.03	2.84	1.00	6.68	Priority 39
Lack of Protection in Material Transportation	2.29	0.97	2.92	1.11	6.68	Priority 39
Misplacing Objects	2.41	0.83	2.70	0.97	6.48	Priority 40

[a]FOC, Frequency of Occurring
[b]SD., Standard Deviation
[c]SEV, Severity of the effects of accident or consequences

In summary, the results support the literature illustrating that lack of safety-forward attitudes, lack of awareness of safety regulations, poor safety awareness of project managers and lack of knowledge are the riskiest construction hazards between studied countries.

6. Conclusion

The key feature of this study is the evaluation of hazards risk level using the risk matrix approach in construction sectors in various countries. It was found that the rates of frequency and severity of identified hazards have no significant difference between developing and developed countries except frequency of poor illumination, poor ventilation, lack of protection in material storage and misplacing objects. Moreover, the results illustrates that there is no significant difference in distribution of severity and frequency of hazards among Malaysia, India, United Kingdom, Australia, and the United States.

It was indicated that the most critical hazards on construction sites are lack of safety-forward attitudes, a lack of awareness of safety regulations, poor safety awareness of project managers and a lack of knowledge. On the contrary, the least critical hazards are misplacing objects, lack of protection in material transportation, lack of innovative technology, and lack of protection in material storage.

The results of risk assessment are appropriate for understanding the risk level of major hazards at the construction sites in order to improve levels of safety risk and hazard prevention that lead to successful safety performance and management. The result of this study is useful for safety officers, safety managers, construction managers, and all participants in construction projects to unify forces and try to mitigate construction accidents by addressing the root causes of accidents.

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