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Exploring the Construction Safety Risk Drivers and Risk Prevention

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Abstract: Construction has long reputation as the riskiest workplace with frequent numbers of incidents and fatal accidents. Previously, hazard identification has drawn sufficient attention from various scholars. However, evident on identification of safety risk drivers that stimulate hazardous conditions in the construction site are still deficient. Therefore, this research aimed at exploring construction safety risk drivers and highlighting risk prevention particularly at the high-rise building construction. A total of 105 samples were gathered from the construction stakeholders in the Malaysian construction industry. Two methods were employed in this research included questionnaire survey and site observation. Data were analyzed using Exploratory Factor Analysis (EFA) with SPSS23 Software and complemented with site photograph interpretation. Twenty one risks drivers were analyzed and results from the EFA managed to rotate five principal factors namely "external drivers", "managerial drivers", "safety performance drivers", "worksite drivers" and "workforce drivers". The highest factor loading was "inadequate safety measures" which was denoted under safety performance drivers while the lowest factor loading was "economic factors" under the external drivers. A total of six factors were identified as critical risk drivers with factor loading more than (Sig. = 0.80) and were further analyzed using site observation approach based on three site profiles to complement the results of EFA. Meanwhile, sixteen factors were analyzed using EFA for risk prevention and managed to rotate two principal factors; "managerial concerns" and "safety and health requirements". These risk prevention were suggested to mitigate the occurrence and consequence of the construction safety risks. The highest factor loading for risk prevention was accounted for "safety and health induction and training" and the lowest factor loading was for "subcontractor selection and management". This research provides novelty in which the focus is on safety risk drivers and risk prevention with unique features using observation analysis to support EFA results. The finding from this research should be able to facilitate the construction practitioners to improve safety risk management in the Malaysian construction industry.

Key words: Construction safety, high-rise building, risk drivers, risk prevention, practitioners

INTRODUCTION

In developed countries, construction industry accounts as a strategic tool in achieving sustainable development. Construction contributes significantly to economy growth, income and employment generation in a country. The challenge of the construction industry at present is to play an integral part in sustainable development without jeopardize environmental, social and wellbeing aspects. Despite numerous benefits offer by the construction industry, it is also recognized as the riskiest workplace (Cheng *et al*., 2004).

The complexity and uncertainty characteristic of the construction site turns it into a host of abundant occupational injuries, diseases and fatalities. Construction workers are likely more vulnerable to injuries and fatalities compared to other industries (Yemul and Darade, 2014). Human errors and poor managerial aspects are always highlighted as the main causes of fatal and non-fatal accidents or near misses.

Hazards scenario arisen from a single or multi risk drivers. For instance, the hazards scenario of hot weather and strenuous work shows the highest factor loading of safety risks in the high-rise building construction in Malaysia (Sofwan *et al*., 2016). The source of the risk is from natural weather which is beyond human control. Proper training which described as risk prevention will drive down the risk of injuries cause by dizziness or sweaty palms and heat-induced illnesses such as heat stroke and heat exhaustion.

Safety risk drivers: Safety risk drivers are an initiating factor in hazards scenario. They are either can decrease or increase the chances for the risk to happen or worsening

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the consequences. The probability of risk is arising from signals conveying the message that a certain risk is likely to occur from unplanned events or circumstances (Malekitabar *et al*., 2016). Risk drivers can be defined as event or condition that stimulates, trigger or delays a potential risk (Vose, 2008). As the indicators of an accident or incident to happen, risk drivers should be explored adequately in predicting the accurate risk identification (Malekitabar *et al*., 2016).

Safety personnel usually predict risk in the construction site from the risk drivers which have been predetermined in the design phase. Knowledgeable workers and other construction stakeholders who encounter past experiences will help the project member to interpret the hint especially when it is recorded and documented well (Perminova *et al*., 2008). Major risk management tools come out with strategic risk control pertaining to the hazard identification but the recognition of the risk drivers in the literature are still limited.

Risk prevention: Over the years, risk prevention practices have been implemented to prevent and mitigate accidents at the construction site (Alarcon *et al*., 2016). However, there is little evidence of the effectiveness of individual or combined practices used by companies to manage occupational safety and health issues. The occurrence and consequences of risks can be mitigated by effective risk prevention throughout the project lifecycle. It needs integrated teamwork between various stakeholders in a construction project. Distinctive strategies have been recommended as tactical planning of risk management.

This study intends to explore and rank construction safety risk drivers. The ranking indicates which drivers stimulate more serious hazards. Strategies on risk prevention will help the stakeholders to emulate the ideas on managing the risks prior to project commencement. Hazard identification allied with their respective risk drivers will give strong foundation of effective risk prevention.

MATERIALS AND METHODS

The literature review from various scholars was undertaken to develop an in-depth understanding of the risk drivers contributing to occurrence of safety risks and the approach of risk prevention to formulate the effective risk management for the high-rise building construction in Malaysia.

Hundred and five sets of questionnaires were received from the construction stakeholders throughout Malaysia. Questionnaires survey were gathered from project manager (21%), project engineer (11.4%), site supervisor (17.1%), health and safety officer (8.6%), site engineer (12.4%), site safety supervisor (18.1%) and others (11.4%). The selected organizations were mainly from G5-G7 contractors with working experience between 5-10 years. The empirical data were analyzed using software of Statistic Package for Social Science (SPSS) version 23. Exploratory Factor Analysis (EFA) was adopted to determine the safety risk drivers and risk prevention.

Table 1: Risk drivers

Risk drivers	Factor loading
External drivers	
Complexity of construction	0.832
Complexity of construction method	0.777
Excessive procedures of government approvals	0.699
Legal factors	0.682
Tight project schedule	0.650
Economic factors	0.542
Managerial drivers	
Insufficient budget allocation	0.768
Allocation of stakeholders responsible	0.768
Insufficient professional/manager	0.617
Lack of coordination between project participants	0.633
Safety performance drivers	
Inadequate safety measures	0.883
Inadequate risk assessment	0.864
Inadequate safety supervision	0.836
Poor management ability	0.773
Communication barriers among workers	0.705
Inadequate site information	0.635
Worksite drivers	
Equipment and machineries	0.858
Working environment	0.851
Working schedule	0.720
Workforce drivers	
Poor labour competency	0.625
Workers attitude and behaviour	0.599

In the EFA procedures, items which possess similar characteristic will be grouped together under one component and summarised using a smaller set of factors or components (Mokhtarian, 2008; Pohlmann, 2008). Therefore, instead of dealing with too many items, the research only dealing with less measuring items. The principal factors should be brief and able to communicate the nature of the underlying construct to get a better interpretation (Field, 2005). The EFA only reports the Bartlett's test of sphericity (Significance value of $p = 0.000$), Kaiser-Mayer-Olkin (KMO) (KMO values close to 1.0) and the output of the total variance explained (eigenvalues exceeding 1.0 or close to 1.0).

The results of EFA of risk drivers were later observed at three selected high-rise construction site in east and west Malaysia.The observation was carried out at three high-rise building construction sites in Kota Kinabalu, Sabah, Miri, Sarawak and Kota Bharu, Kelantan. All these three sites were high-rise building construction project and located at urban area. Photograph interpretation for six main risk drivers was carried out to complement these EFA results. Photograph of six main risk drivers with factor loading of >0.80 are shown in Table 1 for discussion in this study.

RESULTS AND DISCUSSION

Principle components of risk drivers: Table 1 shows results from 105 sets of questionnaire survey. The Bartlett test of sphericity is 1785.578 with significance level of 0.000 and the value of the Kaiser-Mayer Olkin (KMO) measure of sampling adequacy is 0.861 which is higher than 0.50. These demonstrated that the sample met the fundamental requirements for factor analysis (Hair, 2010).

Exploratory Factor Analysis (EFA) managed to rotate five principal components of safety risk drivers. The principal component analysis generated five factor solutions with eigenvalues >1.0. The risk drivers were refined and ranked according to its principal component namely external, managerial, safety performance, worksite and workforce drivers as summarized in Table 2. This research showed that the highest factor loading is inadequate safety measures with factor loading (Sig. = 0.883) which fall under safety performance drivers while the lowest factor loading is accounted for economic factors (Sig. = 0.542) which is denoted under external factors.

Inadequate safety measures at site will drive up danger conditions that will lead to accident or near miss. For instance, refurbishment work in buildings presents high electricity risk. If the electrical work is not properly planned and conducted by qualified electrician, the workers will be exposed to the threat of electrocution and fatal. It is interesting to note that the number of workers electrocuted in the construction industry is higher compared to other industries (Zhao *et al*., 2015).

Therefore, personal actions or behavior on self-protection such as safe work procedures and wearing personal protective equipment to reduce safety risks must be strictly implemented at construction site (Guo *et al*., 2016). From the observation, one of the examples of inadequate safety measures found was insufficient covering of safety net for high rise building as shown in Fig. 1. The edges of the buildings are partly covered with net which give risk to objects falling from height and endanger the workers at lower level. Provision of sufficient safety measures and adoption of safety in design are the accountability of the top management.

On top of that, inadequate risk assessment (Sig. = 0.864), equipment and machineries (Sig. = 0.858), working environment (Sig. = 0.851), inadequate safety supervision (Sig. = 0.836) and complexity of construction (Sig. = 0.832) were categorized as high factor loading. These risk drivers were also deemed to be critical drivers influencing the occurrence of safety risks at high-rise building construction in Malaysia.

Table 2: Risk prevention

Risk prevention	Factor loading
Managerial concerns	
Available technologies	0.834
Involvement key stakeholders	0.829
Upper management commitment	0.798
Sufficient resources allocation	0.793
Subcontractor selection and management	0.693
Safety and health requirements	
Safety and health induction and training	0.901
Safety personal at site	0.872
Frequent workplace inspection	0.852
Safety and health committee	0.841
Risk identification and assessment	0.836
Employee involvement in safety management	0.812
Safety policy of the company	0.803
Record keeping and accident analysis	0.766
Written and comprehensive safety plan	0.748
Incentive, punishment and recognition	0.746
Risk mitigation and emergency response plan	0.736

Fig. 1: Inadequate safety measures

Fig. 2: Inadequate risk assessment

Figure 2 shows an example of inadequate risk assessment on working environment caused by the dumping of commingled construction waste in the building as observed at one of the sites. This pile of waste may obstruct access in the construction area and turn out

to be the breeding sites of aedes mosquito. Deficient risk assessment will drive up the probability of getting dengue fever to the construction workers.

The various equipment and machineries used during construction is depicted in Fig. 3. These machineries need to be used far from pedestrian, regularly inspected, serviced, maintained and stored to drive down the risk of struck by moving machine or injury while handling equipment as provision. The staffs need to be trained prior using the equipment and machineries.

To suit the working environment at high level, the workers should be provided with appropriate personal protection equipment, receive proper training and has height work permit. As observed at one of the sites, the workers were provided with adequate personal protection equipment as portrayed in Fig. 4. This positive measure can drive down the risk of fall from height as it is denoted as the deadliest workplace accident.

Figure 5 demonstrates inadequate safety supervision at sites. The workers were doing their work without sufficient supervision on their safety. This is shown by their unsatisfactory personal protective equipment. Regular supervision by safety personnel is important to identify uncontrolled hazardous exposures to workers, violations of safety standards or regulations or unsafe behavior of workers.

The sixth top ranking risk driver observed and interpreted is complexity of construction. The complexity varies according to the design of the building and (Fig. 6) project itself. This complexity refers to the coordination of the various stakeholders, changing stage and work methods, high uncertainty and risk along with compounded by tight schedule (Bartlett, 2002). As construction is regarded as one of the complex industries, it is inevitable that a greater number of safety risks are inherent with the construction industry.

Skill and decision based error is one of the risk drivers from lack of worker's knowledge, awareness or commitment towards safety procedures and regulations. The consequence of skill and decision-based error is where a worker fails to accomplish a task due to lack of

Fig. 3: Equipment and machineries

Fig. 5: Inadequate safety supervision

Fig. 4: Working environment

Fig. 6: Complexity of construction

good judgement or misperception of risk leading to a wrong decision (Guo *et al*., 2016). These errors arise from adverse circumstances such as abrupt weather changes, poor competency on operating equipment and inadequate work-specific training (Sofwan *et al*., 2016).

The lowest risk driver is represented for workers attitude and behavior and economic factors with factor loading <0.60. Explicit violation of safety rules is an example of poor workers attitude. For instance, the worker disobeys the rule of wearing safety helmet while working due to negligence and lack of attention (Green, 2012). In a nutshell, by recognizing the list of the safety risk drivers, it can provide early notice of potential hazards that might happen in the future. Having so, the stakeholders will mitigate the risk in more effective approach.

Components of risk prevention: A set of risk prevention were arranged in descending order based on two principal factors that were managed to be rotated from the EFA in Table 2. There are sixteen risk preventions which were compounded into two principal factors namely managerial concerns and safety and health requirements. The highest principal factor of managerial concerns was accounted for available technologies with factor loading (Sig. = 0.834) and the lowest factor was subcontractor selection and management with factor loading (Sig. = 0.693).

Most of the construction researchers and safety professionals believed that existing site safety regulations are not sufficient, considering the unsatisfactory safety records in the construction industry. Hence, it is necessary to add an extra level of safety measures to protect construction workers. One of the proactive safety measures is to provide adequate technologies for example equipment-workers close proximity warnings (Green, 2012).

The complexity and ambiguity inherent in the nature of the construction industry requires safety planners to adopt recent and innovative technologies to make sure they are covering predictable surprises as much as possible. Integrated design approaches accompanied by multidimensional visualization technology and Building Information Modeling (BIM) has assisted in the automated risk identification, assessment and mitigation of construction safety risks during the design phase (Malekitabar *et al*., 2016).

From this research viewpoint, subcontractor selection and management was perceived as the least favor risk prevention. This is due to the common practices in selecting the subcontractors based on their skills and competencies.

The highest factor loading under safety and health management was for safety and health induction and training with (Sig. = 0.901). Induction and training is a part of administrative control. Every worker should be equipped with adequate training before executing any works. Competency training for example is the pre-requisite for hazardous task such as working in confined space. The lowest factor loading was for risk mitigation and emergency response plan (Sig. = 0.736) because most of the respondents perceived it as not an urgent concern.

CONCLUSION

Collectively, the findings revealed a number of safety risk drivers that give signal to preceded events or hazards scenario that can lead to accident or near miss. The findings revealed that six risk drivers were considered critical which is above (Sig. = 0.80) factor loading while two risk drivers were considered less critical which is below (Sig. = 0.60) factor loading. Meanwhile, for risk prevention, nine factors were measured as critical and none with less critical. No statistical relationship between risks drivers and risk prevention were demonstrated in this research. Hence, future studies need to develop relationship between risk drivers and risk prevention. This study provided significant drivers which stimulate more severe consequences and recommended the favorable risk prevention for successful risk management at the construction site.

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