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Identifying and assessing the critical factors for effective implementation of safety programs in construction projects

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ABSTRACT

Safety issues are considered as the major concerns in the construction industry. Despite the rapid advancement of technology, it is revealed that the rate of the fatality in the construction industry is extremely high. Safety programs implemented by contractors, has always been known as one of the most effective strategies to reduce accidents and injuries in construction sites. There are myriad studies conducted to determine and evaluate the relative effectiveness of critical safety program factors; however, the interactions among these factors have rarely been investigated. The aim of this paper is to identify and assess the causal relationships of safety program factors in the construction projects in Kuala Lumpur, capital of Malaysia. First, Fuzzy Delphi Method (FDM) was used to identify the safety program factors. Second, Decision-Making Trial and Evaluation Laboratory (DEMATEL), which is a multiple criteria analysis tool, was employed to investigate the interdependences among the safety program factors. Then, the causal relationships among all safety program factors were visualized through a cause-effect relationship diagram. In this paper, 11 safety program factors were identified through FDM. Finally, the obtained results from DEMATEL indicate that "Safety Commitment and Responsibilities", "Sub-Contractors and Personnel's Selection", "Safety Supervisor and Professionals", "Plan for safety", and "Employee Involvement and Safety Evaluation" are critical safety program factors. It was concluded that focusing on these five influencing factors results in the improvement of all safety program factors.

1. Introduction

Construction industry is regarded as a dangerous industry, while plays an important role to satisfy human development needs (Haadir, 2011; Ramli et al., 2013). Researchers in different studies have revealed that fatality rate in construction industry is extremely high (Cheng et al., 2010; Chong, 2014; Im et al., 2009; Pinto et al., 2011). Wamuziri (2006) stated that those who spend their working lives on construction sites have a one in 300 chances of being killed at work. According to the National Safety Council reports (Council et al., 2013), 10,000 people died in past fifteen years at construction work- places in the United States, which was the highest number of fatalities among deaths occurring in all types of industries over this period of time (Mahmoudi et al., 2014).

The proportions of accidents on construction sites in developing countries are relatively high (Gangolells et al., 2010; Murie, 2007; NSC, 2013). Malaysian construction industry with the highest rate of fatality between 2009 and 2016 is considered as one of the most dangerous industries in recent years (DOSH, 2017). The construction sector in Malaysia experienced 58 deaths (the highest rate of death in comparison with other industries), 11 permanent disability cases and 101 non-permanent disability cases in 2016 (DOSH, 2017). Although the construction sector was accounted for only 7% of occupational accidents, most of them have ended as fatality (DOSH, 2017).

The major causes of construction accidents are related to the unique nature of the industry. Unique characteristics, distinguish the construction industry from other industries and contribute to a high accident rate construction sites (Aminbakhsh et al., 2013; Fredericks et al., 2005). Characteristics such as dynamic work environments, extensive use of sophisticated plants, heavy equipment, and multiplicity of operations turned construction sites to a hazardous place. Construction accidents and injuries bring direct and indirect expenses. Direct expenses include medical costs and workers' compensation insurance, while indirect expenses contain delay in construction progress, worker's motivation diminishing, and adverse effects on reputation of the construction companies (Mahmoudi et al., 2014; Wang et al., 2006). A study conducted by Darshi (2005) revealed the non-material expenses of accidents, i.e. pain, suffering expenses and loss of life quality, and

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Table 1
Construction safety program factors.

Factors	Description	References
Safety Incentive	Safety incentive is one of the proactive techniques utilized by management to motivate employees to work safely. The incentives can be financial or nonfinancial awards to encourage employees to be involved in safety programs	El-Mashaleh et al. (2010b) Ghasemi et al. (2015), Hallowell et al. (2013), Rajendran and Gambatese (2009), Wanberg et al. (2013)
Safety Training	A vital factor of a successful safety program is to periodically train and educate all employees to enhance their knowledge and skill about safety at work. For new employees, safety orientation is necessary to inform them about safety goals	Cheng and Li (2004), Cooper (2000), Fernández-Muñiz et al. (2007), Hallowell et al. (2013), Hill (2004), Huang and Hinze (2006), Law et al. (2006), Tam et al. (2004)
Safety Supervisor and Professionals	Safety supervisors and professionals play an important role in ensuring safety at the workplace as they perform and direct the implementation of safety program factors and serve as a resource for employees	Aksorn and Hadikusumo (2008a), Fang et al. (2004), Haadir (2011), Priyadarshani et al. (2013), Rajendran and Gambatese (2009)
Safety Commitment and Responsibilities	Management commitment to comply with safety requirements such as participating in regular safety meetings, determine clear safety responsibilities among management and personnel, serving on committees, and providing funding for other safety and health program elements	Aksorn and Hadikusumo (2008b), Fang et al. (2004), Hassan et al. (2007), Hsu et al. (2008), Jaselskis et al. (1996), Rajendran and Gambatese (2009), Yung (2009)
Safety Inspections and Job Hazard Analyses	The goal of safety inspection is to assess physical working condition of site to determine uncontrolled and potential hazardous exposures to employees	Priyadarshani et al. (2013), Rajendran and Gambatese (2009), Teo et al. (2005), Toole (2002), Wilson and Koehn (2000), Yung (2009)
Sub-Contractors and Personnel's Selection	Selecting sub-contractors and personnel by considering their safety and health performance. Only subcontractors with demonstrated ability to work safely should be qualified to attend in bidding process	Hallowell and Gambatese (2009a), Hallowell et al. (2013), Hansen (2006), Hinze and Gambatese (2003), Rajendran and Gambatese (2009)
Emergency Response Plan	Emergency response plan involves making a plan to follow in the case of critical situation or severe accidents such as fatality or incidents that led to serious injuries	Hallowell and Gambatese (2009a), Ismail et al. (2012b), Priyadarshani et al. (2013), Rajendran and Gambatese (2009), Rowlinson (2004)
Worker's Fatigue-management Program	The goal of this program is to decrease the level of production and work pressure on workers by managing their working ours	El-Mashaleh et al. (2010a), Hinze and Gambatese (2003), Hinze et al. (2013a), Lee et al. (2005), Nepal et al. (2006), Wu et al. (2015)
Employee Involvement and Safety Evaluation	All employees should be involved in implementation of safety program tasks such as participating in safety meeting and toolbox talks, conducting safety committee, and stopping work authority by workers. Subsequently, an organized safety evaluation procedure in essential to check its success in meeting defined objectives	Abudayyeh et al. (2006), Aksorn and Hadikusumo (2008a), Findley et al. (2004), Hallowell and Gambatese (2009a), Raja Prasad and Reghunath (2011), Wu et al. (2015), Yung (2009)
Ergonomic Task Checking	The goal is to perform comprehensive ergonomic task checking and determine ergonomic risk elements to prevent ergonomic injuries	(Hallowell and Gambatese, 2007; Mitropoulos et al., 2009; Rajendran, 2006; Rajendran and Gambatese, 2009)
Alcohol and Substance Abuse Programs	The goal is to identify and prevent alcohol and substance abuse in workplace by testing employees randomly	Hallowell et al. (2013), Hinze and Gambatese (2003), Rajendran and Gambatese (2009)
Accident and Near Miss Investigation	It involves recording and reporting the information and specifics of all accidents or near misses to facilitate analyses of accident data, identify the errors, and apply corrective actions	Anton (1989), Cambraia et al. (2010), Ghasemi et al. (2015), Hallowell and Gambatese (2009a), Hinze et al. (2013b), Ismail et al. (2012b), Rowlinson (2004), Wu et al. (2010)
Plan for Safety	A safety and health plan in the early stages served as the foundation of any effective safety program, which included documentation of project-specific safety and health goals, policies and procedures that are known to maintain safe working environment	Hallowell (2011), Hallowell and Gambatese (2009a), Jaselskis et al. (1996), Ng et al. (2005), Rajendran and Gambatese (2009), Teo et al. (2005), Yung (2009)
Worker-to-worker Observation	Observing workers by a worker or any person that may take a few minutes, or it could take a few hours	Aksorn and Hadikusumo (2008a), Hinze and Godfrey (2003), Hinze et al. (2013a), Ismail et al. (2012b)

mentioned that these expenses were almost 30% of direct accident expenses. With the increasing costs of accidents, professionals have realized that even one incident might bankrupt the company due to the lawsuits and claims against the owner (Alpmen, 2013).

Safety program as a proactive approach, is known as the foremost technique to improve safety at construction projects (Tam et al., 2004). A successful safety program can significantly decrease the accident rate as it requires management to employ safe construction procedures and prepare a safe working environment for the employees (Haadir, 2011; Rowlinson, 2004). Furthermore, good safety culture is another achievement that can be obtained through the application of an effective safety program since it demands a cooperation between management and employees in the implementation of the programs (Hallowell et al., 2013). It is extremely important to identify the factors and elements influencing safety programs in construction projects in order to improve its operational effectiveness. Since most of the construction companies allocate limited resources to safety management, contractors are forced to select a limited subset of the available elements (Priyadarshani et al., 2013). This situation raised a concern of, "what are the most appropriate program factors to improve and control health and safety in construction projects?"

Various researchers tried to answer the above-mentioned question and identify the critical factors affect safety performance of construction projects. Mostly, these researches evaluate the relative effectiveness of safety program factors by measuring the amount of risk reduced by each factor. However, during evaluating process, each factor was assessed individually, and minimal effort has been made to investigate the interactions among safety program factors specifically (Hallowell and Gambatese, 2009a; Li, 2009). The aim of this paper is to identify and assess the critical safety program factors through investigating the relationships and interactions between these factors in construction projects in Kuala Lumpur, capital of Malaysia. An extensive literature was reviewed regarding independent factors of an effective construction safety and health programs. Then, Fuzzy Delphi Method (FDM) was used to identify the significant factors of an effective construction safety programs. Subsequently, decision-making trial and evaluation laboratory (DEMATEL) was employed to develop a network structure of interdependent safety program factors. Utilizing this method, the causal interactions between safety program factors were visualized through a cause- effect diagram and a dependency matrix.