Accident Analysis and Prevention 93 (2016) 267–279

Contents lists available at ScienceDirect

Accident Analysis and Prevention

journal homepage: www.elsevier.com/locate/aap

Critical factors and paths influencing construction workers' safety risk tolerances

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ARTICLE INFO

Article history:
Received 3 August 2015
Received in revised form 2 November 2015
Accepted 21 November 2015
Available online 13 January 2016

Keywords:
Risk tolerance
Construction
Safety risk
Safety management
Personal subjective perception
System thinking

ABSTRACT

While workers' safety risk tolerances have been regarded as a main reason for their unsafe behaviors, little is known about why different people have different risk tolerances even when confronting the same situation. The aim of this research is to identify the critical factors and paths that influence workers' safety risk tolerance and to explore how they contribute to accident causal model from a system thinking perceptive. A number of methods were carried out to analyze the data collected through interviews and questionnaire surveys. In the first and second steps of the research, factor identification, factor ranking and factor analysis were carried out, and the results show that workers' safety risk tolerance can be influenced by four groups of factors, namely: (1) personal subjective perception; (2) work knowledge and experiences; (3) work characteristics; and (4) safety management. In the third step of the research, hypothetical influencing path model was developed and tested by using structural equation modeling (SEM). It is found that the effects of external factors (safety management and work characteristics) on risk tolerance are larger than that of internal factors (personal subjective perception and work knowledge & experiences). Specifically, safety management contributes the most to workers' safety risk tolerance through its direct effect and indirect effect; while personal subjective perception comes the second and can act as an intermedia for work characteristics. This research provides an in-depth insight of workers' unsafe behaviors by depicting the contributing factors as shown in the accident causal model developed in this research.

1. Introduction

Practically, the development of construction industry has been plagued by the accidents or injuries that are frequently occurred. It is estimated that there are around 60,000 construction fatalities occurred worldwide each year, which equates to one accident happens every nine minutes (ILO, 2006). Further, the construction industry employs nearly 10% of the workforce but it accounts for 20–40% of the occupational fatal accidents (Raheem and Hinze, 2014). These highly disproportionate numbers indicate a deteriorating situation of construction industry. A thorough understanding of the accident causation mechanism is essential for accident prevention. Heinrich et al. (1950) advocated that accidents are caused by an unsafe act (e.g., an individual's behavior or activity that deviates from normal accepted safety procedure) or an unsafe condition (e.g., deficiency in machines and materials). Research has found that, 88% of accidents are caused by the former, and 10% by the later (Heinrich et al., 1950). Garrett and Teizer (2009) also pointed out that human error is a main reason for up to 80% of all incidents and accidents in complex high-risk industry such as mining, construction and nuclear power. Further, Fang (2012) asserted that workers' unsafe behaviors have been recognized as the direct and common reason for construction accidents. Since the characteristics of construction work determine workers usually work on separate sites, this decentralization makes it more difficult to identify and manage unsafe behaviors (Olson and Austin, 2001; Gould and Joyce, 2003).

Theoretically, workers' internal factors such as attitude, perception and efficacy play a vital role in safety performance. As shown in Fig. 1, unsafe behavior and unsafe condition have been recognized as the main reasons for construction accidents, and among these two, unsafe conditions can resulted from misusing of equipment (i.e., workers are not familiar with crane operating) or deficient

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http://dx.doi.org/10.1016/j.aap.2015.11.027
0001-4575/

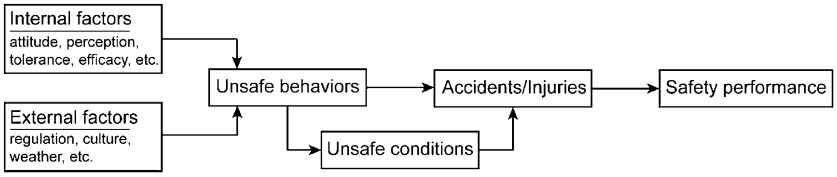

Fig. 1. A general accident casual model.

management (i.e., sloppy material test). It has been proven that the reasons of unsafe behaviors can be explained from two aspects: (1) internal factors: which means personal characteristics, such as risk perception, risk attitude, risk tolerance, self-efficacy and stress (Hallowell, 2010; Wang and Yuan, 2011; Wang, 2014; Dixit et al., 2014; Leung et al., 2012); and (2) external factors, which refers to the environment in which individuals are living, such as culture, regulations and weather (de Camprieu et al., 2007; Liu et al., 2014; Acar and Göç, 2011). After an accident happens, project safety performance is negatively influenced. Workers who experienced or witnessed injures tend to be more risk aversion and less optimistic (Shin et al., 2014). As a result, unsafe behaviors can be reduced. Then, less accidents and better safety performance would occur. Accordingly, the changes of individuals' internal factors will determine the performance of construction safety. In other words, they act as the input of accident causal model. And thus, exploration of factors contributing different internal factors is vital for successful accident prevention from a system thinking perceptive (Fung et al., 2012). Having said so, it is worth noting that from a system perspective, there is normally a feedback loop which represents that the input factors (i.e., the causes) are also affected by the outputs (i.e., safety performance). This will be discussed in details at later sections.

Previous studies have shown that non-objective risk assessment would happen if taking no consideration of individuals' risk tolerance (Hopkinson, 2012; Mu et al., 2014). Lichtenstein et al. (1978) pointed out that people tend to overestimate their ability to control or prevent accidents, thus leads to an underestimation of the risks. Balaz and Williams (2011) emphasized the effect of risk tolerance on immigrants' risk perceptions, and showed that the more uncertainties immigrants can accept, the more likely they underestimate the seriousness of potential risks. Basically, individuals with higher (lower) risk tolerance are more (less) likely to take a risk. Therefore, objective assessment of risk tolerance plays a critical role in an effective and successful safe behavior. Decisions made without considering risk tolerance might not be persuasive or reliable. Nevertheless, which factors influence workers' safety risk tolerance and to what extent the factors can affect remained as important and unsolved problems.

System thinking, as a discipline of seeing systems holistically (Goh et al., 2010) has been used for construction safety improvement. For example, Leveson (2004) developed a new accident model based on system thinking, and proved that it can provide better and less subjective understanding of the reasons and preventions of accidents. Goh et al. (2010) built a causal loop diagram to simulate the relationships between safety culture and major accidents. Their results illustrated that an amalgamation reaction from each part can promote poor safety culture even though each of them are necessary from each party's point of view. Shin et al. (2014) developed a system dynamics model to analyze the feedback mechanisms and the resultant dynamics regarding workers' safety attitudes and safe behaviors. It is summarized that systematic thinking are effective in representing the complex interactions between factors and making the accident be more readily understood.

Accordingly, investigating reasons behind different assessments of risk tolerance and introducing them into accident causal model would be helpful to reveal the causes of workers' unsafe behaviors, and tailored prevention actions can be developed. This paper starts from a review of the literature depicting what risk tolerance is and why it plays an important role in risk management. Then the research instruments and methods adopted in this study are introduced. Afterwards, it is the identification of critical factors influencing workers' safety risk tolerance and the analysis of the interactions between critical factors and recognizing the key influencing paths. The critical influencing factors are then introduced into the accident causal model. It is expected that the findings of this research not only contributes to the knowledge body of systematic safety risk management, but also serves as practical guidance for construction safety management.

2. Risk tolerance and its function in risk management

A major issue within the literature of risk tolerance is the lack of general agreement regarding the definition of this concept. From the perceptive of governmental agencies, the Securities and Exchange Commission (SEC) made an explanation of risk tolerance as "your ability and willingness to lose some or all of your original investment in exchange for greater potential returns" (SEC, 2010). It is applied by the Financial Industry Regulatory Authority (FINRA) (2011) as "a guideline to define risk tolerance". The ISO31000 Guide 73:2009 defines a more general risk tolerance as "organization's or stakeholder's readiness to bear the risk after risk treatment in order to achieve its objective". In addition, some researchers also give their explanations of risk tolerance. Irwin (1993) defined financial risk tolerance as "the willingness to engage in behaviors in which the outcomes remain uncertain with the possibility of an identifiable negative outcome". Grable (2000) explained the conception as "investors' tolerance toward financial risk refers to the amount of uncertainty or investment return volatility that an investor is willing to accept when making a financial decision". It should be noticed that the definitions present above are focused on the financial field. From the perspective of risk behavior and decision making, Hunter (2002) gave a definition as "the amount of risks that individuals are willing to accept in the pursuit of some goal". Roszkowski and Davey (2010) also agreed that this definition can provide better understanding of decision makers' risk tolerance.

Based on the above definitions, there are some key words that indicate risk tolerance contains two aspects: (1) subjective, e.g., willingness and readiness, which address whether people want to take risks; and (2) objective, e.g., ability, amount of uncertainties and amount of risks, which refers that how many losses can individuals tolerant. Some researchers have realized the complicacy in risk tolerance. Burton (1996) proposed that risk tolerance can be in two parts: subjective risk tolerance, which was based on the economic concept of risk aversion; objective risk tolerance, which refers to individuals' financial situation, including investment horizon for each goal. Similarly, Cordell (2002) contended that risk tolerance should be separated into risk capacity and risk attitude, among them, risk capacity is more an objective measure which includes income and financial stability. In contrast, risk attitude is more a