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A Bayesian Belief Network model of organizational factors for improving safe work behaviors in Thai construction industry

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ABSTRACT

Organizational factors and human factors are intimately related and intermingled with each other. Therefore, development of the implications for improving work safety behaviors is difficult due to the complexities of multiple causal relations of those factors within construction safety scenarios.

With an aim towards identifying the particular implications for enhancing the desired behaviors or mitigating unfavorable behaviors, Bayesian network was therefore selected as an analytical technique for providing insight into the influence of the relevant contributories by investigating variations in the output of networks. Bayesian Belief Networks have been extensively applied in research because of their capability to capture sophisticated inferences. In addition, researchers are enabled to deliberately investigate the expected consequences of uncertainty prior to establishing an effective intervention. As a result, the present alternatives highlight the useful implications that might lead to the highest probability of safe work behavior. Based on this Bayesian network, an improvement in safe work behavior can be obtained by controlling leadership, management commitment, participation, and the perceived behavioral control node. Accordingly, it is increasingly being acknowledged that management must demonstrate substantive and visible commitment to occupational safety. In addition, managers at all levels must play an important role in establishing a supportive and participative atmosphere to encourage subordinates to work in a safer way. This application and the findings from the empirical evidence of the Bayesian Belief Network can explore the influence of organizational factors and their impact on safe work behavior through manipulating a combination of organizational factors.

1. Introduction

Several studies have investigated and developed safety management theories in an attempt to understand accident causation and avoidance. A series of publications have shown that people are the predominant reason for the problems (Vredenburgh, 2002; Mullen, 2004). Not only people are acknowledged as the contributing factor, but organizational factors shape the context that contributes to at-risk work behavior and human error (Gordon, 1998; Papazoglou and Aneziris, 1999). Several investigations of common major occupational accidents have demonstrated interest in the role of organizational factors to improve the worker behavior. Investigations and evidences manifest that "the root causes involved more than technical or human failures" (Seo, 2005). In addition, a number of studies have shown that organizational factors considerably influence at-risk work behaviors (Oliver et al., 2002). Thus, organizational factors have been recognized as the means of mitigating accidents in the workplace. For this reason, organizational factors and human factors are recognized as related and intermingled. While these two factors play an important role in occupational safety, they are examined separately from one another (Gordon, 1998; Weil and Apostolakis, 2001).

Several studies have been conducted to identify the organizational factors that influence work behavior, for example Jitwasinkul and Hadikusumo (2011) identified a set of 22 organizational factors including organizational culture, ownership, safety culture, leadership, personnel selection, reward system, resource allocation, communication, management commitment, coordination of work, formalization, organizational knowledge, empowerment, centralization, goal prioritization, organizational learning, technical knowledge, time urgency, problem identification, role/responsibilities, performance evaluation, and training that affect occupational safety in construction projects. This initial set is an adequate starting place to develop the guidelines to encourage safe work behavior in construction. Attempts have been made to

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identify and clarify organizational factors that affect occupational safety behavior, as well as the specific organizational context within which it is essential that these factors can be examined. In terms of occupational health and safety, a number of analytical approaches have been utilized to examine the influence of contributories as well as to identify the particular implications for enhancing desired behavior or mitigating unfavorable behavior. However, it is not easy to determine the implications for improvement of safe work behavior in conjunction with the influence of organizational factors because of the complexities of the multiple causal relationships between organizational factors, psychological precursors, and safe work behaviors, especially in complex construction industry safety scenarios. Therefore, an appropriate analytical approach should be capable to handle the complex causality and provide strategies to enhance safe work behavior in terms of their interactions among organizational factors, psychological precursors, and individual safe work behavior within the built environment.

2. Network development

The Bayesian Belief Network (BBN) has laid the ground for a probabilistic analytical approach to a wide range of problem domains. The ability to update and revise the belief values allows probabilistic networks to examine complex inference arenas such as sensitivity analysis, the value of information, and rational decision-making systems. Furthermore, these networks substantially support causality analysis as well as thorough statistical induction. These capabilities are useful for determining the form of automated learning, which can involve causal relationship discovery, network discovery, and parameter discovery (Kjaerulff and Madsen). In particular, BBN can perform four kind of reasoning namely; predictive, diagnostic, inter-causal, and combined reasoning. Thus, BBN is becoming a progressively essential analytical approach for research and application in numerous academic fields. Since BBN may provide insight into the influence of the relevant contributories through an investigation of the variation in network outputs, researchers can deliberate the expected consequences from uncertainty prior to establishing an effective intervention.

Theoretically, BBN is represented by directed acyclic graphs (DAGs). DAGs provide major advantages that enable experts and researchers to construct complex causal relationships in which nodes represent stochastic variables and directed edges (arrows) indicate direct probabilistic dependencies among the relevant variables. DAGs are also able to encode deterministic as well as probabilistic relationships among the variables. Each node contains a conditional probability table (CPT) and the state of the random variable that it represents. The conditional probability table of each node is comprised of the probabilities of the node according to a certain state, given the state of its parent nodes. For example, the probabilistic relationship between A and B is represented by P(A|B). This means that the probability of the event A, given that event B has already occurred. Generally, complicated relations among relevant factors and work behaviors have been acknowledged. These factors have direct or indirect influences on safe work behavior, especially in the relationship between organizational factors and the psychological precursors of safe work behavior. Zhou et al. (2008) conducted a pilot study in order to develop an application for analyzing safety behavior in construction projects. The findings showed that BBN is capable of investigating the complex relationships between safe work behavior and their contributories. Hence, this study adopted BBN as analytical tool for examining the influence of organizational factors through psychological precursors in order to provide an understanding of organizational factors related to safe work behavior. The Netica software package from Norsys Software Corp. was used in this study.

2.1. Identifying the psychological precursors

The emergence of numerous behavioral causation models has created a mixture of theoretical concepts and various determinants. Similarities and overlapping psychological precursors cause unnecessary predictors. They are too numerous for the creation of work behavior analysis, and some are too encompassing to benefit behavioral prediction. According to a critical review of the behavioral literature, the Theory of Planned Behavior (TPB) may be one appropriate among work-related behavior models, because it has particular characteristics that consist of precursor intent constructs covering a wide range of motivation, intention, and behavior interaction. The proof of validity is examined by a number of empirical studies in behavioral science (Armitage and Arden, 2002; Johnson and Hall, 2005). For this reason, this study adopts TPB as a reasonable basis for the development of BBN, explaining the influence of organizational factors on safe work behavior. This model is comprised of four primary precursors, including attitude, subjective norm, perceived behavioral control, and intention.

First, attitude is an important element of the behavioral mechanism according to safe work behavior. It is defined as a "predetermined set of responses, built up as a result of experience of similar situations, a way of responding to a situation, or a tendency to respond positively or negatively to certain persons, objects or situations" (Stranks, 1994). Second, subjective norms determine the effect of social influences on the behavioral intention of the individual (Johnson and Hall, 2005). In other words, this subjective norm involves all participants who are associated with a certain joint action. Third, perceived behavioral control represents a belief according to the opportunities and access to resources required to perceive behavior. In other words, it is determined by two fundamental elements (Johnson and Hall, 2005). The first component relates to the availability of resources required to engage in the given behavior. This may involve access to time, budget, and other resources. The second component reflects the individual's self-confidence in the ability to perform the given behavior. As an example, consider a frontline worker confronting a situation in which workers have to work at a height. The frontline worker may accept the significance of the supervisor's opinions; meanwhile, the importance of these opinions may be clouded by each worker's perception of frontline practices as a barrier to work safely.

2.2. Formulating the hypothetical network of organizational factors

The organizational factors are of vital importance for improving the efficiency of promoting safe work behavior and encouraging participation in safety initiatives as well as safety compliance. A system theory of accident causation involves the relevance of interaction between person, machine and environment. The proposition of this concept is to encourage managers to interrelate the organization with its members and view the organization both as a whole and as part of a larger environment system. Seven important organizational factors are identified out of twenty-two: management commitment, communication, leadership, reward system, empowerment, organization learning and culture (Jitwasinkul and Hadikusumo, 2011). Development of a hypothetical network is based on the mechanism of implications of organizational factors. Prior to presenting the network, brief discussion of each organizational factor is provided here.

First of all, it is known that management commitment affects safe work behavior. Visible efforts by management exhibit the deeper values and shared understanding held by management (Michael et al., 2005; Fernández-Muñiz et al., 2007; Geldart et al., 2010). Langford et al. (2000) mentioned that when operatives believe that management cares about their personal safety, they