Safety Science 89 (2016) 240–248

Contents lists available at ScienceDirect

Safety Science

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

Evaluation of construction projects based on the safe work behavior of co-employees through a neural network model

D.A. Patel [a,*], K.N. Jha [b]

[a] Civil Engineering Department, S.V. National Institute of Technology (SV-NIT), Surat 395007, Gujarat, India
[b] Department of Civil Engineering, Indian Institute of Technology Delhi, Hauz Khas, New Delhi 110016, India

ARTICLE INFO

Article history:
Received 23 March 2015
Received in revised form 10 December 2015
Accepted 24 June 2016

Keywords:
Behavior
Neural network
Safety climate
Prediction
India

ABSTRACT

The safety climate of an organization influences employees' safe work behavior. It is essential for project management to be aware of any unsafe work behavior of their workers on a project and to take any necessary remedial measures to reduce the likelihood of accidents. This study aims to predict and evaluate the work behavior of employees on construction projects using the constructs of the safety climate. Because of the prevailing nonlinear and complex interrelationships among these determinants, an artificial neural network (ANN) is employed to develop the model. Ten important safety climate features are used as inputs, and co-employees' safe work behavior is taken as the output. A total of 240 responses from different construction projects across India were collected through a questionnaire in a two-stage process to train, test, and validate the model. A three-layer feedforward backpropagation neural network architecture 10-17-1 was found to be a suitable model. Through this model, outlier projects have been determined based on the project efficiency score and the Anderson-Darling (AD) statistics. The study advocates the practice of safe work behavior as reported by co-employees, rather than workers' own reported safe work behavior, as the output variable. The significant constructs of safe work behavior are presented based on the sensitivity analysis. This model will be helpful to evaluate, predict, and monitor the safety performance of construction projects.

1. Introduction

A global workplace concern is how to improve safety performance on construction projects. However, a large number of countries, including India, do not properly report and publish accident statistics on occupational injuries and illnesses (Hamalainen et al., 2006). Patel and Jha (2014) attempted to compile construction accident statistics from different organizations of state and center governments but found that some of the data published seemed to be underestimated. Because of the unavailability of reliable accident statistics (reactive indicators), proactive indicators such as safe work behavior may be useful to study the safety performance of construction projects (Hinze, 2013). Kaila (2006) believes that 80–95% of all accidents are due to unsafe behavior and actions. Thus, identification of unsafe work behavior of employees in advance may help considerably in the development of remedial measures and strategic actions to prevent accidents.

Worker behavior is influenced by the safety climate, which comprises a number of elements. However, considering the nonlinear and complex relationship that exists between the constructs of safety climate and the safe work behavior of employees, an artificial neural network (ANN) may be used to evaluate and predict safe work behavior. Moreover, there are still some issues regarding how to measure safe work behavior of employees and identify outliers among different construction projects. Patel and Jha (2014) developed an ANN-based model to predict safe work behavior of employees on construction projects using self-reported measures of workers' safe work behavior. However, because it relies on self-reporting, this approach is subject to bias. The current study uses an alternative behavioral measure, that of coworkers reporting on other workers' safe behavior. Thus, this study proposes another approach of behavior measurement of co-employees and compares it with the approach used by Patel and Jha (2014), thereby expanding their previous work.

The study's prime objectives were to: (1) develop an ANN-based model to predict and evaluate construction employees' safe work behavior using co-employees' reports, and (2) evaluate and identify outliers on construction projects based on co-employees' reports of other employees' safe work behavior.

* Corresponding author.
E-mail addresses: dapscholar@gmail.com (D.A. Patel), knjha@civil.iitd.ac.in (K.N. Jha).

http://dx.doi.org/10.1016/j.ssci.2016.06.020
0925-7535/

2. Literature review

In the existing literature, many accident theories and models are available. Khanzode et al. (2012) categorized these theories and models in four generations: first generation (accident proneness theory); second generation (domino theories); third generation (injury epidemiology theory); fourth generation (system theories, sociotechnical system theory, macro ergonomic theory). Accident proneness and domino theories postulate that an unsafe act by a person or an unsafe condition is the domino that triggers the sequence leading to injuries (e.g., in construction). Between these two aspects of unsafe work practices and unsafe working conditions, Garavan et al. (2001) and Hoyos (1995) attribute a majority to the former. Lingard and Rowlinson (2005) also back this result, arguing that 80–90% of all accidents are caused by unsafe behavior—in particular, behavior that could have been controlled by the employee or checked by management. If such behavior can be corrected by diligent management, the etiology of several accidents could be limited.

A behavior-based approach to safety performance is more sensitive and effective than conventional measures such as reactive indicators of safety performance. Moreover, the use of a behavior-based approach highlights the unsafe behavior of workers before the occurrence of any accident, thereby giving it greater value as a preventive approach (Thompson et al., 1998; Lingard and Rowlinson, 1998; Mohamed, 2002; Cooper and Phillips, 2004; Chen and Jin, 2012).

In the safety science literature, construction workers' behavior is strongly associated with the safety climate—broadly defined as the perception of the state of safety at a given time. According to Guldenmund (2000), safety culture includes aspects of the organization culture that will influence attitudes and behavior related to increasing or decreasing risk. The safety climate is a valuable snapshot of the safety culture that prevails in a work environment, even though it is a temporal phenomenon that is relatively unstable and subject to change because of its dependence on intangible issues such as situational and environmental factors (Wiegmann et al., 2004). One can refer to Reason (1997), Guldenmund (2000), and Glendon and Stanton (2000) for a better explanation regarding interrelationships prevailing among organization culture, safety culture and safety climate. Several theoretical models have been presented to study the interrelationships among safety climate, safety culture, safety behavior of workers, and accident statistics (Geller, 1994; Cooper, 2000; Neal et al., 2000; Cooper and Phillips, 2004; Choudhry et al., 2007; Zhou et al., 2008).

Mohamed (2002) studied the relationships between the constructs of the safety climate and self-reported safe work behavior in construction site environments using structural equation modeling (SEM). Seo (2005) identified the safety climate as the best early indicator of unsafe work behavior, noting three influences as: (a) indirect influences through a chain of other mediating factors; (b) direct influences on factors affecting unsafe working, and (c) direct influences on unsafe work behavior. Using correlations and structural equation modeling, Johnson (2007) found that the safety climate could predict safety behavior and injury severity, as measured by work absences. Pousette et al. (2008) found that the safety climate could also be an important predictor of the safety behavior of construction workers. They also reported that safety climate scores at one point in time (time one) significantly predicted self-reported safety behavior at time two, seven months later (after controlling for safety behavior at time one). The literature therefore reveals that the safety climate can be used as a predictor of unsafe work behavior of people associated with execution of construction projects.

Many researchers have used different constructs of safety climate in their studies (Zohar, 1980; Brown and Holmes, 1986). DeDobbeleer and Béland (1991) examined the safety climate model presented by Brown and Holmes (1986) and concluded that the blind acceptance of a measurement model for the assessment of latent constructs may lead to serious error. Chen and Jin (2013) used the 15 most frequently used safety climate/culture constructs based on a review of 33 relevant papers. Of these 15 features, Chen and Jin (2013) found that management attitudes/commitments (21 mentions), safety procedures/policies/rules (15), perception of risk (11), attitudes towards safety (10), and communication (10) were most frequently mentioned. However, no consensus was found on the factor structure of the safety climate (Flin et al., 2000; Mohamed, 2002; Mearns et al., 2003). In existing literature, the inconsistencies associated with various constructs and their different characteristics pose difficulty in deciding which of them best represent a transparent and full picture of the safety climate. However, 10 important features of a safety climate are congruent with the empirical evidence in construction environments and have been used by several authors (Zohar, 1980; Mohamed, 2002; Fang et al., 2006). These components are shown with brief explanations in Table 1, along with references to the studies using these components.

Table 1
List of ten safety climate components and their brief explanations.

Components (Inputs)	Explanation
Commitment	This refers to the perception of management commitment to health and safety within the organization
Communication	'Communication between employees and employer' can identify safety-related problems in advance
Safety rules and procedures	Workers must perceive the necessity and efficacy of current 'safety rules and procedures' in the organization because the comprehension of this promotes safety in the workplace
Supportive environment	The involvement of the workers and the support of coworkers within the organization are related to the social environment of the workplace
Supervisory environment	Supervisors implement safety rules and regulations, framed by top management onsite. A healthy supervisory environment motivates the workers to follow safety rules
Employees' involvement	This addresses the extent to which the employees (workers) are involved in hazard identification, safety planning and safety activities such as inspections, accident investigations, development of safety interventions and policies, and reporting of injuries
Personal appreciation of risk	This refers to the overall attitudes toward safety. There is an association between personal perception of risks and individuals' willingness to take risks
Appraisal of physical work environment and work hazard	This reflects the presence of hazards in the working environment and the need for proper site layouts. Workplace hazards were defined as tangible factors that may pose risks of possible accidents
Work pressure	This refers to the degree to which employees feel induced to complete work. This affects the time available for planning and execution of the construction work following the safety rules
Competence	This refers to the general level of workers' qualification, experience, skills, knowledge and training. Many researchers emphasize the training of workers, especially for hazard identification, which is a major factor affecting safety at a construction site (Jaselisks et al., 1996)