Structural Equation Modeling for Relationship-Based Determinants of Safety Performance in Construction Projects

D. A. Patel[1] and K. N. Jha[2]

Abstract: Safety performance in construction projects is attributed to many determinants (factors) in a safety system. This study identifies various directly or indirectly related determinants and their effects on safety performance of construction projects. Using structural equation modeling (SEM), this study empirically examines the effect of safety climate (SC), hazard management (HM), safety budget (SB), safety rules and regulations (SR), and safe work behavior (WB) of employees and workers on safety performance (SP) of projects. The unit of analysis of this study is a construction project. A questionnaire survey was conducted, and 230 responses were collected from different types of construction projects across India. The results provide evidence that safety climate, safety budget, and hazard management positively influence safe work behavior of employees and the safety performance of the project. Conversely, the SEM findings demonstrate that implementation of safety rules and regulations are positively but weakly related to safe work behavior of employees, although they positively and more strongly influence the safety performance of the project. On the basis of these empirical results, the study advocates allocating a sufficient safety budget to Indian construction projects. It also recommends considering the effects of the safety rules and regulations on safe work behavior of employees and workers while framing and revising them. **DOI: 10.1061/(ASCE)ME.1943-5479.0000457.** © *2016 American Society of Civil Engineers.*

Author keywords: Safety performance; Safety climate; Safety budget; Safety rules and regulations; Work behavior; Structural equation modeling (SEM); India.

Introduction

Safety is a basic physical and psychological need of human beings (Zou 2011). However, safety issues become challenging in the construction sector because of the dynamic nature of projects, the involvement of many stakeholders, and the presence of a large number of unskilled laborers. The Indian construction industry works under a less controlled environment compared with the manufacturing industry; thus, naturally there are pronounced differences in the safety culture of two industries. The Indian construction sector is the country's second-largest employer (Patel and Jha 2014). However, construction workers are generally illiterate and unskilled in India. They migrate temporarily to far-away cities in search of jobs. The different groups of workers employed in a project come from different cultures and speak different languages. Furthermore, compared with other process industries, the construction industry is characterized by its dynamic and unique nature, multiple tasks and activities, use of many resources, poor working conditions, unsteady employment, multiple contract system, competition, and tough environments. It adds to the challenges in managing the safety in the Indian construction (Patel 2015).

Moreover, safety management is a multidisciplinary subject (Benjamin 2008). Therefore, practitioners always find it difficult to understand the critical determinants of safety performance and their relationship toward the safety performance of a project. Perhaps this is one of the major reasons to overlook safety issues in the construction industry. Therefore, to improve the safety performance of projects, one needs to explore, study, and understand the critical determinants and their direct or indirect relationships to safety performance. In this study, some hypotheses are formulated and tested by using the structural equation modeling (SEM) approach.

Point of Departure

Based on the existing literature, the hypothesized model of the safety system is presented as shown in Fig. 1, in which the safety system has been broadly categorized in four parts: input, process, output, and outcomes. As inputs, project hazard, human error, and natural calamity are uncertain events that exist in each project, and they may cause an accident. To prevent the occurrence of an accident, these inputs can be controlled by developing a safety management system and using proper resources, which may be called *process*. Reason (1997) introduced the idea of a safety space with extreme resistance and extreme vulnerability as two opposite sides of the safety space. An organization's location within the safety space depends on how well the organization manages its hazards (inputs).

The process adopted in an organization comprises a set of policies and practices aimed at positively affecting the employees' attitudes and behaviors with regard to risk, thereby reducing their unsafe acts. The process raises awareness, understanding, motivation, and commitment among workers (Fernandez-Muniz et al. 2007). According to the behavior approach, the main cause of

[1]Assistant Professor, Dept. of Civil Engineering, Sardar Vallabh National Institute of Technology Surat, Surat, Gujarat 395007, India (corresponding author). E-mail: dapscholar@gmail.com

[2]Associate Professor, Dept. of Civil Engineering, Indian Institute of Technology Delhi, Hauz Khas, New Delhi 110016, India. E-mail: knjha@civil.iitd.ac.in

Note. This manuscript was submitted on September 18, 2015; approved on February 25, 2016; published online on May 10, 2016. Discussion period open until October 10, 2016; separate discussions must be submitted for individual papers. This paper is part of the ***Journal of Management in Engineering***, © ASCE, ISSN 0742-597X.

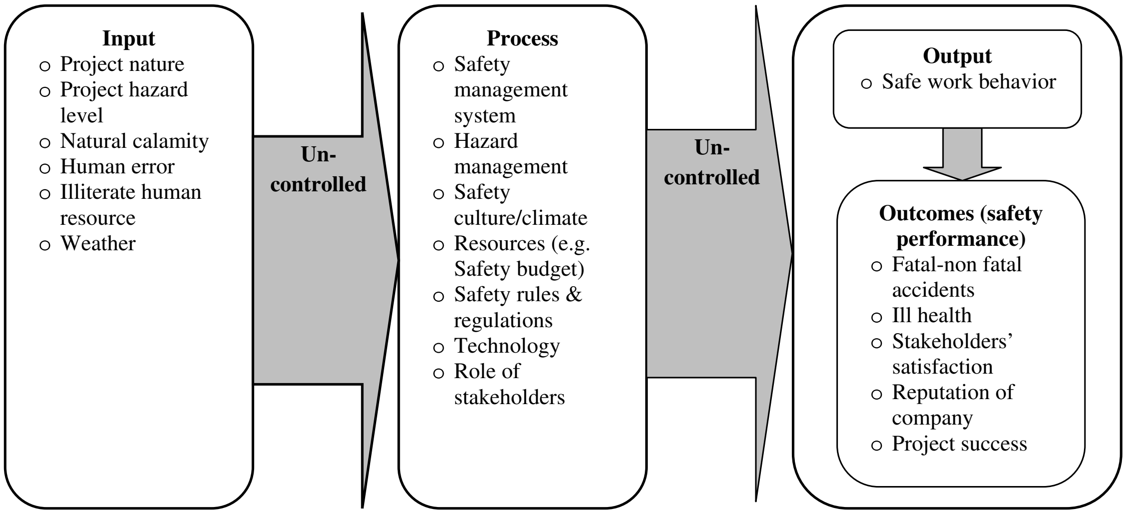


Fig. 1. Holistic framework of construction safety

any accident is the unsafe work behavior of workers. To control the work behavior of workers, different elements such as safety management system, safety climate, safety budget, hazard management, safety rules and regulations (policy), and so on are considered part of the process in the safety system. Thus, the process of the system controls the work behavior and directly or indirectly manages the safety performance of a project.

However, because of the interrelationship among elements in the process, the safety system becomes messy and complex, which leads to difficulty in understanding its individual influence on safety output and outcomes. Consequently, it confuses management in making strategic decisions for managing safety performance in a construction project. Therefore, this study identifies limited but important process elements such as hazard management (HM), safety rules and regulations (SR), safety climate (SC), and safety budget (SB) and investigates how they affect safe work behavior (WB) of employees and the overall safety performance (SP) of the project. There is a need to study the interrelationships among these determinants of safety performance.

Objectives of the Study

Therefore, the main objectives of the study are (1) to select important determinants of safe performance, formulate hypotheses, and develop a measurement model; (2) to validate the measurement model; and (3) to develop a path model and conduct path analysis for its validation.

Literature Review

This section briefly reviews the important determinants of safety performance, formulates hypotheses, and introduces SEM and its applications.

Hazard Management

The project hazard is a natural part of any construction project condition owing to its scope and location. A higher project hazard level tends to be associated with a higher on-site risk level (Imriyas et al. 2008). However, project safety depends on the magnitude of the management program and the project hazard level of a project. Unidentified hazards negate the risk assessment process (Carter and Smith 2006). Hazard management plays an important role in managing the safety performance of a project. Hazard management includes identifying, evaluating, and controlling the hazards at construction projects. Hazards can be identified by reviewing method statements, guidelines, reports, brainstorming, and experience. The evaluation of hazard attributes is difficult because of its vague nature. However, Imriyas et al. (2008) and Patel and Jha (2015) developed a project hazard index (PHI) to evaluate the project hazard level. Feng (2013) studied the impact of the project hazard level on safety performance and found that the highest level of safety investment occurs with the highest project hazard level in building projects. In brief, existing literature can assist in deciding the indicators that reflect the level of hazard management in a construction project.

Safety Climate

For the last two decades, safety climate and safety culture in occupational health and safety (OHS) have been vital subjects of research among the researchers and consultants in each construction sector worldwide because the safety culture plays a role in preventing accidents at sites. The safety climate describes "the way we do things" (Choudhry et al. 2007). Wiegmann et al. (2004) explained safety climate as a psychological phenomenon that is usually the perception of the state of safety at a particular time. It is closely concerned with intangible issues such as situational and environmental factors. Furthermore, safety climate is also a temporal phenomenon, a "snapshot" of safety culture, relatively unstable and subject to change. Several researchers have studied the interrelation between safety climate and other determinants of safety performance. Cooper and Phillips (2004) reported the lack of a direct link between safety climate and safe behavior in their study, whereas Mohamed (2002) found a correlation between them. These contradictory results may create confusion. Therefore, one needs to study and test the interrelationship between the safety climate and safe work behavior of workers in the context of the Indian construction industry.

Safety Budget

Safety budget (safety investment) refers to the expenditure incurred against pursuing people's health, security of life, and living safeguard (Hinze 2000). Enough safety budgets protect the health and physical integrity of workers and the material assets of a contractor (Tang et al. 1997). According to Hinze (2000), the costs of safety are incurred as a result of an emphasis being placed on safety, whether it may be in the form of training, drug testing, safety incentives, staffing for safety, personal protection equipment, safety programs, and so on. In addition, Hinze (2000) believes that investments in safety must be viewed as a means to improve the bottom line and, naturally, to reduce the incidence of injuries rather than just an operational cost. However, Aksorn and Hadikusumo (2008) found a large gap between the degree of importance and actual status in sufficient resource allocation, particularly in the safety budget when studying the safety program in the Thai construction industry. Nonetheless, this impact is largely an issue of probabilities, as there might be no injuries even if there is no investment in safety. Hinze (2000) developed and presented a decision tree that explains the various possible outcomes related to emphasizing safety and incurring injuries. If the investments in safety are high, the probability of incurring high injury cost becomes relatively small. Conversely, if the investments in safety are low, the chance of sustaining high injury cost can be relatively high. However, in India, construction companies often decide their projects' safety budgets according to rules of thumb rather than a standard practice because of a lack of established guidelines on estimating safety budgets. Also, available data on exact figures of safety budgets for projects are lacking; thus, this study considers safety budgets as a latent factor and prefers to determine indicators to establish linkages with other determinants of safety performance. According to the literature [IS 14489-1998 (BIS 1998); Hinze 2000; Fang et al. 2004], some indicators can be selected to represent the safety budget of the project.

Safety Rules and Regulations

Safety rules and regulations are subsets of the OHS policy of the government and companies (Koehn 1983; Benjamin 2008; ILO 2005; Li and Poon 2013). The articulation of such a policy by the government and companies reaffirms their commitment to the cause of safe working environments and enables them to comply with their moral and international obligations (Benjamin 2008). As a policy factor, legislation provides a framework in which health and safety is regulated and controlled (Rowlinson 2004). Zhou et al. (2015) found that safety rules and regulations are significant for accident prevention and accident cost reduction. Li and Poon (2013) noted that a series of initiatives in the form of legislation, law enforcement, and safety training effectively reduce the number of industrial fatalities in the Hong Kong construction industry. Some researchers studied the impacts of the legislation or enforcement protocols on safety management in various countries. Siriruttanapruk and Anuntakulnathi (2004) pointed out that the poor level of safety in the Thai construction industry is primarily because of inadequate implementation of safety programs and weak enforcement of legislation.

Mahalingam et al. (2007) studied the issues of construction safety in global projects and found that enforcement was effective in improving short-term safety and one-time projects in developing countries such as India and Taiwan. Teo and Ling (2006) developed a model to measure the effectiveness of construction site health and safety management. The model was based on 3P + I, where "3P" represented policy factors, process factors, and personnel factors, and "I" represented incentive factors. Several researchers (Sawacha et al. 1999; Hinze and Wilson 1999; Jaselisks et al. 1996) noted that an organization's safety policy influences safety performance in the construction sector. Ng et al. (2005) presented a framework of safety performance evaluation (SPE) that considered various factors at a project and organization level and found that legislation, codes, and standards were important safety factors at organizational levels. El-Mashaleh et al. (2010) proposed a hypothesis that safety performance and organization safety policy are positively correlated and suggested testing it in further study. Nonetheless, according to Khanzode et al. (2012), the effects of enforcement of safety laws on injury reduction are not thoroughly researched and reported in the previous research. In this connection, it is interesting to study whether the current safety rules and regulations are correlated with safe work behavior of workers and safety performance of the project.

Safety Performance and Safe Work Behavior

Safety performance is a part of the total performance of an organization (Wu et al. 2008). Evaluation of safety performance makes it possible to assess the effect of specific changes that the company may wish to make. Ingalls (1999) summarized the reasons to measure safety performance: it enables reasoned decisions and assessments; it allows comparison with previous (or others') performance; and compares actual performance with planned performance. Therefore, it is important to have a reliable measure to evaluate the safety performance. The reliable measure will be consistent in its value. However, a common definition of safety performance is not available in existing literature. Therefore, there is a need to select such indicators of safety performance, which can represent the safety performance (latent factor) (Hair et al. 2014). Safety performance improvements in an organization can increase its resistance or robustness and lower the risk of accidents.

Thus, safety performance is neither physically measurable nor presented easily. Therefore, it is a latent variable. However, safety performance is linked to the occurrence of fatal and nonfatal accidents (reactive measures) at sites. If the number of accidents is high, safety performance is lower, and vice versa. Therefore, safety performance and the number of accidents are inversely associated. The main purpose of measuring health and safety performance is to provide information on the progress and current status of the strategies, processes, and activities used by an organization to control risks to health and safety (HSE 2001).

Many researchers advocate the use of proactive measures (e.g., jobsite safety inspections, behavior-based worker observations, and worker safety perception surveys), which focus on current safety activities to ascertain system success rather than system failure (Hinze and Godfrey 2003; Cooper and Phillips 2004). In fact, both reactive and proactive measures have advantages and disadvantages.

There is probably no single leading indicator that actually provides a measure that reflects input from every aspect of the safety program. The choice of safety performance measures or indicators relies on the purpose of measurement. In developing countries such as India, there are no sincere practices to compile, maintain, and publish accident statistics accurately (Patel and Jha 2014). Sometimes, even reputed companies may not be willing to share real accident and injury data for their projects. The unavailability of accident statistics is a hurdle in researching on construction safety in India. However, this study can adopt safe work behavior of workers and safety performance of projects as latent factors in the safety system, and their indicators could be easily decided by referring to the literature.

On the basis of the review of existing literature, the following hypotheses are formulated:

1. Hazard management is positively related to the safe work behavior of workers.

2. Safety climate is positively related to the safe work behavior of workers.
3. Safety budget is positively related to the safe work behavior of workers.
4. Safety rules and regulations are positively related to the safe work behavior of workers.
5. Safe work behavior of workers is related positively to the safety performance.

As mentioned earlier, hazard management, safety rules and regulations, safety climate, safety budget, safe work behavior, and safety performance are the latent factors, and there may be causal relationships among them. In these circumstances, SEM may be appropriate in studying the cause-and-effect relationships among these latent constructs that are indicated by multiple measures. In addition, SEM takes a hypothesis-testing approach by using multivariate analysis of a structural theory, and one can stipulate causal relationships among multiple variables.

Structural Equation Modeling

Structural equation modeling is a general term that describes a large number of statistical models used to evaluate the validity of substantive theories with empirical data. Statistically, it refers to an extension of general linear modeling (GLM) procedures, like the ANOVA and multiple regression analysis. Structural equation modeling performs better than multiple regression in the modeling of interactions, nonlinearities, correlated independents, measurement error, correlated error terms, and multiple latent independents each measured by multiple indicators. Therefore, several researchers (Paul and Maiti 2007; Ozorhon et al. 2010; Tabish and Jha 2012; Chen et al. 2012; Xiong et al. 2015; Fang et al. 2015) preferred to use the SEM in construction management area including safety management owing to its quasi-routine and even indispensable statistical analysis approach in the social sciences. Thus, existing literature reveals the soundness and applicability of SEM in this study.

Research Method

This section follows the guidelines to develop the SEM suggested by Hair et al. (2014) to achieve the research objectives. As shown in Fig. 2, six steps are suggested for SEM to test measurement theory and validate with confirmatory factor analysis (CFA). As discussed previously, the SEM analysis is conducted by using a two-phase approach. The first four steps are associated with CFA to validate the measurement model and the remaining two steps are associated with path analysis to examine the structure (path model).

To Define Individual Constructs

Factor analysis fundamentally presumes that, in a given domain, there is a small number of unobservable latent constructs, also known as common factors, which influence the potentially vast array of observed variables. Conversely, the purpose of CFA is to statistically test the ability of the hypothesized factor model to reproduce the sampled data (i.e., usually the variance-covariance matrix). Therefore, latent factors and their attributes (indicators) are predetermined to measure the safety performance of construction projects. Hair et al. (2014) suggest literature review for the individual construct to identify and use prior scales published in academic studies. As discussed previously, important determinants for safety performance such as HM, SC, SR, SB, WB, and SP are considered for this model. Besides, on the basis of the existing literature, the measures (indicators) of each latent factor have also been determined as shown in Table 1.

It is an important task to decide indicators of each latent factor. For example, the indicator WB1 ("I follow all the safety procedures for the jobs that I perform") is related to both WB and SR. If the indicator is put into the wrong category, this may result in irrelevant conclusions from the statistical analysis. To avoid this, content validity has been checked according to the discussion with experts and the existing literature as shown in Table 1. Statistical parameters will not allow establishing a measurement model if appropriate indicators of latent factors are not properly chosen. The indicators have been chosen after considering the type of projects, organizations involved with the project, involvement of all stakeholders, competence of the respondents, and interaction with experts.

To Establish the Overall Measurement Model

Numerous indicators may be used to fully represent the construct and maximize reliability; however, parsimony leads to use the smallest number of indicators to adequately represent a construct. Hair et al. (2014) recommend a minimum of three indicators per construct as good practice. Therefore, to develop the hypothetical and measurement model, this study identified six latent variables and their 20 measurable variables as shown in Table 1. A set of measure indicators is explained by only one underlying construct; therefore, all measures are unidimensional measures. Furthermore, the measurable variables used in the SEM should be continuous variables and easily measurable. As mentioned previously, according to the existing literature review and interviews with several safety professionals in the construction sector, this study has formulated hypotheses, on the basis of which a hypothetical model is illustrated in Fig. 3(a). In Figs. 3(a and b), the arrows show the direction of the hypothesized influence. The value of the arrow is the estimate (factor loading) that reflects the strength of the

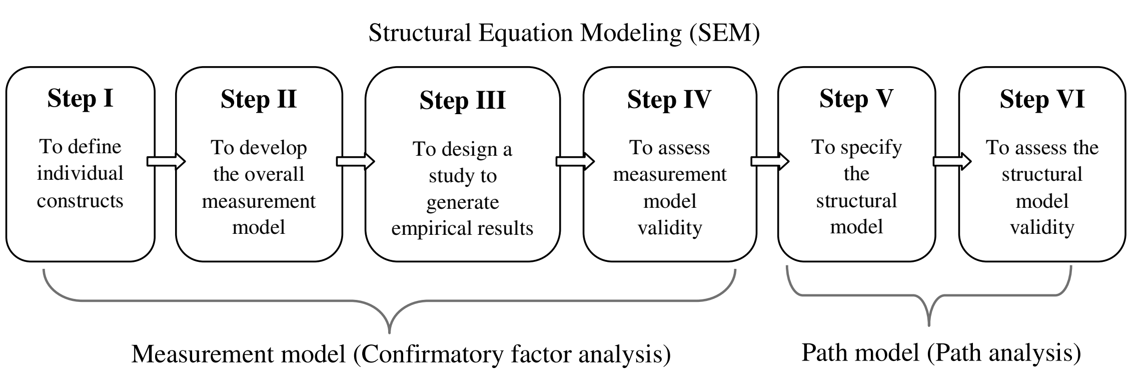


Fig. 2. Research methodology

Table 1. Latent Factors and Their Indicators

Latent factors	Indicators	Total score	References
Hazard management (HM)	I feel that everyone plays an active role in identifying site hazards (HM1)	1,531	Molenaar et al. (2009), Manuele (2010), and IS 14489:1998 (BIS 1998)
	Detecting potential hazards is a major aim of the site planning exercise (HM2)	1,556	
	We have knowledge of overall hazards in our project (HM3)	1,606	
Safety climate (SC)	Safety climate in my current work place reduces occupational risk (SC1)	1,576	Zohar (1980), Brown et al. (1986), De Dobbeleer et al. (1991), HSE (2001), Mohamed (2002), and Neal and Griffin (2006)
	The safety procedures and practices in this organization are useful and effective (SC2)	1,602	
	Safety climate in my current work place inspires to work safely (SC3)	1,627	
Safety budget (SB)	Our company provides adequate personal protective equipment (PPE) to each worker (SB1)	1,669	Hinze (2000), Fang et al. (2004), and IS14489:1998 (BIS 1998)
	Company pays for the medical expenses of injured workers (SB2)	1,710	
	How do you rate the safety budget in the project? (SB3)	1,460	
Safety rules and regulations (SR)	Safety inspections are regularly carried out by safety officer/safety supervisors (SR1)	1,677	Mohamed (2002) and Teo et al. (2006)
	Safety inspection is conducted by top management and project manager (SR2)	1,598	
	Safety inspections/meetings are conducted by client (representative) (SR3)	1,557	
	We sincerely attempt correction of nonconformities raised by client/its representative/certification body (SR4)	1,590	
	The information about hazard level is communicated by concerned authority to workers (SR5)	1,532	
Work behavior (WB)	I follow all the safety procedures for the jobs that I perform (WB1)	1,538	Mohamed (2002), Cooper and Phillips (2004), and Hinze et al. (2013)
	All workers and employees follow all the safety procedures for the jobs that they perform (WB2)	1,648	
	All workers and employees enjoy their jobs at sites (WB3)	1,563	
Safety performance (SP)	I am satisfied with the safety performance of my project (SP1)	1,581	Wu et al. (2008)
	How do you rate overall safety performance of the project? (SP2)	1,610	
	In my opinion, my project can achieve the status of the zero-incident project (SP3)	1,613	

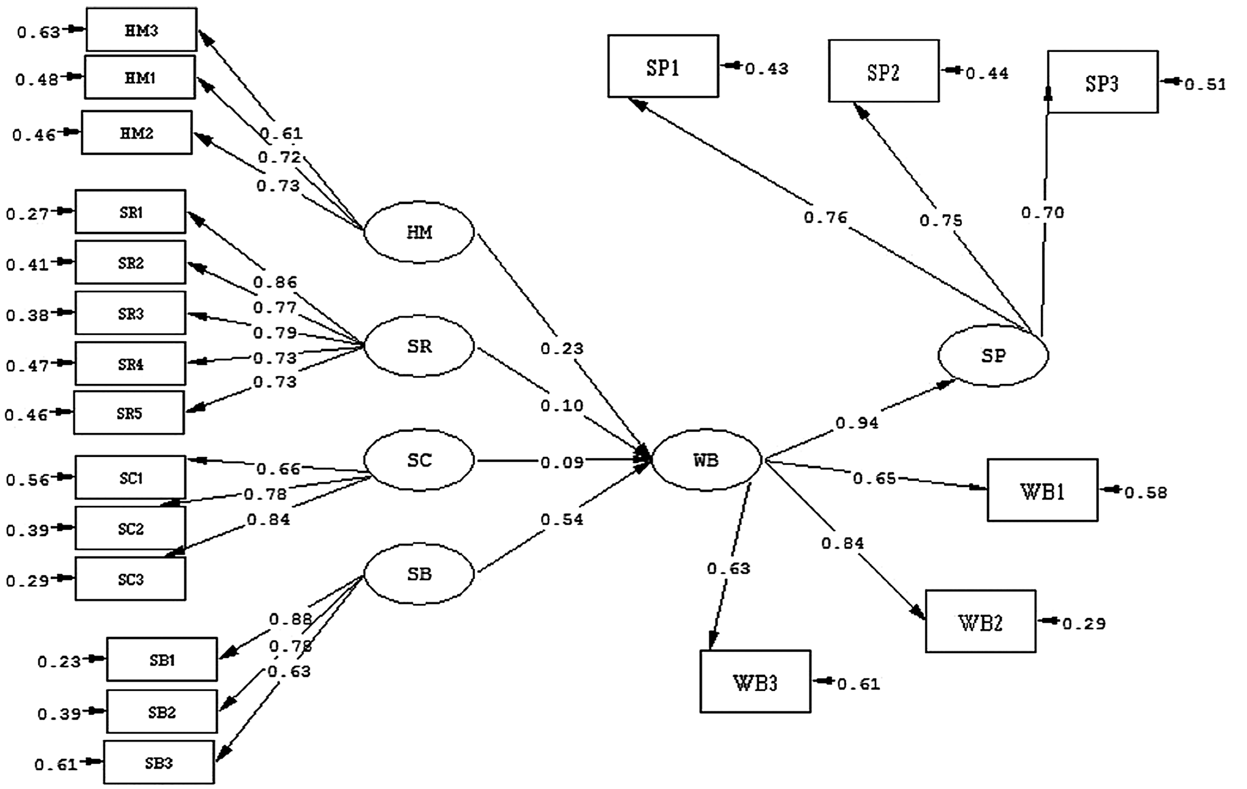
relationship between construct and indicator or another construct. The constructs (latent factors) are oval, and their indicators are rectangle.

A questionnaire was designed to collect data for developing the model. All measures were assessed on the same scale using a nine-point Likert scale from "strongly disagree (1)" to "strongly agree (9)" (Tabish 2011). Each of the measures is equally weighted, and the total score of each question is given in Table 1. The questionnaire survey was performed by face-to-face meetings and by sending emails for a good response rate and quality. By conducting face-to-face meetings with respondents at the project sites, 219 samples were collected, whereas 11 samples were obtained through emails.

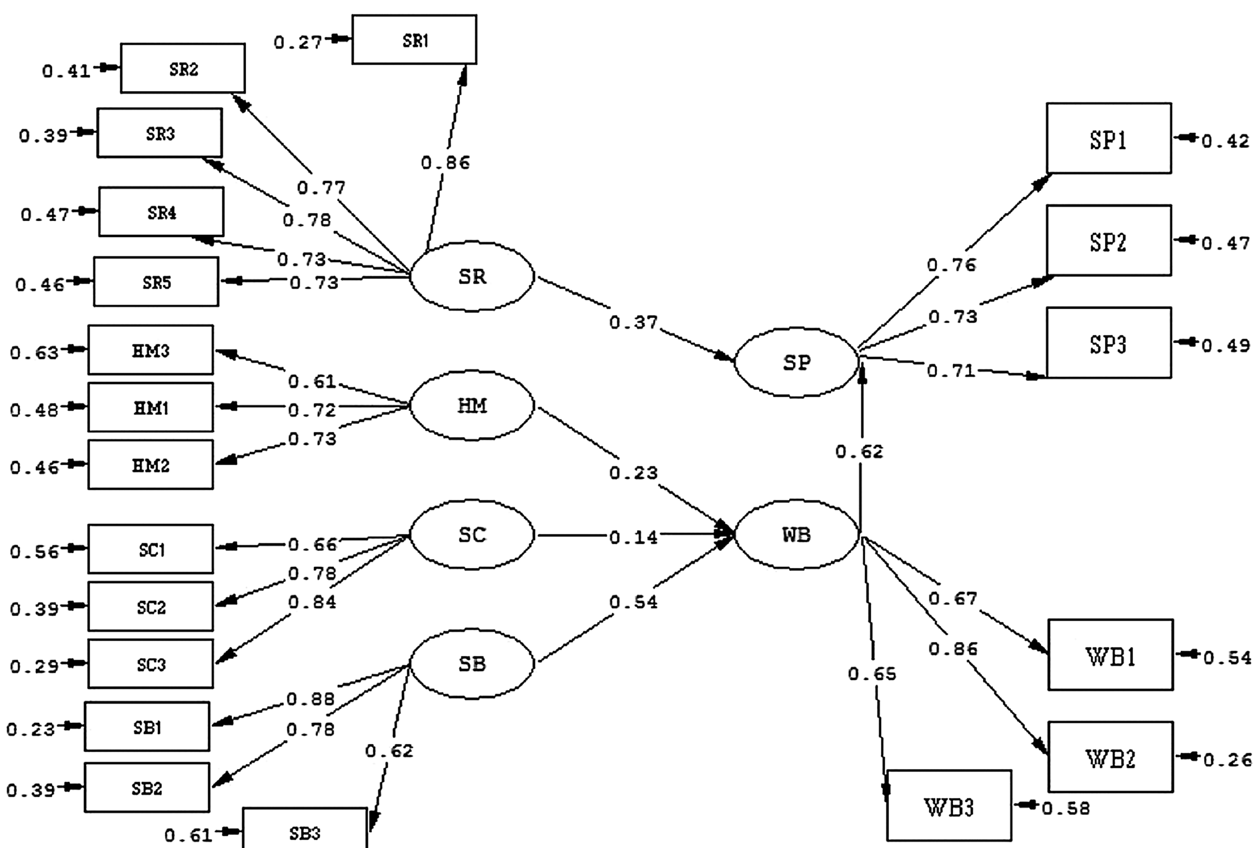
If the participant had any doubt or misunderstanding about any question, it could be clarified easily in face-to-face meetings. Besides, these meetings also reduced the number of unanswered questions, thus overcoming the problem of missing data. The Indian construction industry is assumed as the population for the study, and a construction project site is a unit of analysis. Moreover, the SEM is a large-sample technique (usually $N > 200$), and the sample size required is somewhat dependent on the estimation method used, the distributional characteristics of observed variables, and model complexity (Kline 1998). Thus, a total of 230 samples of data were collected from various project sites across India. The data consisted of 94 responses from the Delhi metro construction, 56 from highway construction, 42 from residential buildings, 28 from industrial buildings, and 10 from nuclear plant projects.

The cost of each project was more than 500 million Indian rupees. All projects were randomly selected through available information obtained from personal contacts, broadcast media, press releases, reports, websites, and others. The target respondents are employees of the contractor and client, mainly consisting of site engineers, safety officers, project managers, planning engineers, and others, who are directly associated with execution of the work and possess a minimum of 3 years' experience on projects to ensure the reliability of the received responses. The average experience of respondents from the Delhi metro construction, highway, residential building, industrial building, and nuclear plant projects was found to be 15.78, 12.09, 7.50, 10.00, and 11.63 years, respectively. Thus, the average experience of all respondents is 11.4 years. At least three responses per project site were collected to minimize the bias. Considering distribution of samples and average experience of respondents in respective projects, Delhi metro construction projects may influence the result of this study.

The sampling frame includes companies that are the members of Construction Industry Council of India (CIDC) New Delhi. These companies are big and self-performing work organizations and have established safety management system in their projects. They regularly organize safety trainings, meetings, audits, and other safety programs. All stakeholders of these projects were actively associated with safety programs.



(a)



(b)

Fig. 3. (a) Hypothetical model; (b) revised model

The measures of the latent factors have been decided on the basis of the existing literature as shown in Table 1. The face-to-face meetings and eligibility criteria of respondents adopted in the research method were able to provide confidence that the respondents would understand the questionnaire thoroughly and respond accordingly. Therefore, it was assumed that the respondents understood and responded properly against all indicators of latent factors.

Cronbach's alpha reliability test was performed to analyze the appropriateness of the grouping of constructs of safety performance and the reliability of the data. The alpha value ranges from 0 to 1. Values of alpha ranging from 0.6 to 0.7 are considered as sufficient; a value of more than 0.7 is considered as good in reliability testing (Hair et al. 2014).

To Design a Study to Generate Empirical Results

Covariance matrices have distinct statistical advantages over correlation matrices (Hair et al. 2014; Schumaker and Lomax 2004); therefore, this study prefers to use covariance matrices in the SEM analysis. Moreover, missing data, outlier, multivariate normality, sample size, estimation technique, model complexity, and communality are important criteria when developing a model. In the collected samples, missing data of 12 cases were imputed by using the expectation maximization (EM) algorithm, and 10 outliers were detected by using the Mahalanobis D^2 formula and thus were removed from further analysis. Kaiser-Meyer-Olkin (KMO) and Bartlett's test of sphericity are also conducted to take care of sampling adequacy and multivariate normality.

Hair et al. (2014) suggest a minimum sample size of 150 in the SEM if there are seven or less constructs, with modest communalities (0.5) in case of not having any underidentified construct. Communalities reflect the average of variation among the measured variables (indicators) explained by the measurement model. Maximum likelihood estimation (MLE) is selected as an estimation technique, as it provides valid and stable results even in a smaller sample size of 50 (Hair et al. 2014). However, this study has a sample size of 220 (after removing outliers), which may be considered enough to take care of these issues. The *LISREL 8.8* software is used in development model because of its user-friendly approach. The order and rank conditions are considered to avoid identification problems. The degree of freedom for a model should be greater than zero. In other words, the number of unique covariance and variance should be higher than the number of free-parameter estimates. This is an order condition and reflects the underidentified model. The rank conditions are controlled by avoiding cross loadings among different constructs in the model. Besides, it is also ensured to have at least three indicators per construct.

To Assess Measurement Model Validity

Measurement model validity relies on establishing acceptable levels of specific evidence of construct validity and goodness of fit for the measurement model. Once the measurement model is correctly specified, both reliability (construct and item) and validity (convergent, discriminant, face, and nomological) are tested. Their brief explanations and their permissible ranges are given in Table 2.

If the variance-covariance matrix estimated by the model does not adequately replicate the sample variance-covariance matrix, the model could be improved and retested, presuming that the model is identifiable. Following the model modification, the parameters of the specified model are re-estimated before attaining a specified SEM model. In brief, up to this step, this study confirms the latent factors and their indicators by testing the different parameter to develop the structural model.

To Specify the Structural Model

The basic objective of this step is to specify the structural model relationship as replacements for the correlation relationship obtained in the CFA model. Specification involves identifying the set of relationships someone wants to examine and determining how to specify these variables in the model, keeping in mind that specifying a relationship needs theoretical or empirical support. On the basis of the hypotheses, a structure is built as shown in Fig. 3(a). All latent factors are exogenous constructs, except safety performance and safe work behavior, which are endogenous constructs. In this step, the parameters are determined to be fixed or free.

Table 2. Explanation on Reliability and Validity

Checks	Parameters	Explanations	Permissible limit
Reliability (precision or consistency of a measure)	Construct reliability	It refers to the degree to which an observed instrument reflects an underlying factor. It is computed from the squared sum of factor loadings for each construct and the sum of the error variance terms for a construct.	A construct reliability value of 0.6 and 0.7 may be acceptable (Hair et al. 2014).
	Item reliability	It refers to the amount of variance in an item attributed to underlying constructs rather than to error and can be obtained by squaring the factor loadings.	It should be greater than 0.50 (Hair et al. 2014).
Validity (extent to which research is accurate)	Convergent validity	It refers to the degree to which indicators of the same constructs should converge or share a high proportion of various in common (highly correlated). Average variance extracted, factor loading, and communality are used to assess convergent validity.	The AVE, factor loading, and communality should be 0.50, 0.70, and 0.50, respectively, or higher (Fornell and Larcker 1981; Hair et al. 2014).
	Discriminant validity	Discriminant validity refers to the degree to which conceptually similar concepts are distinct. The measures of theoretically different constructs should have low correlations with each other. According to Fornell and Larcker (1981), discriminant validity can be checked by using the AVE, too.	The AVE of each construct should be higher than the squared correlations between the construct and all other constructs in the model.
	Face validity	It refers to understanding of every item's meaning or content.	Based on existing literature
	Nomological validity	It refers to whether the correlations among the constructs in a measurement theory make sense.	Based on existing literature

Table 3. Estimation of Parameters for CFA

Latent factors	Indicators	Cronbach's alpha	Factor loading	Unique variance	Communality	AVE	CR	R^2
HM	HM1	0.711	0.72	0.48	0.52	0.47	0.73	0.52
	HM2		0.73	0.47	0.53			0.54
	HM3		0.61	0.63	0.37			0.37
SC	SC1	0.801	0.67	0.55	0.45	0.59	0.81	0.44
	SC2		0.78	0.39	0.61			0.61
	SC3		0.84	0.29	0.71			0.70
SB	SB1	0.781	0.86	0.26	0.74	0.59	0.81	0.75
	SB2		0.77	0.41	0.59			0.60
	SB3		0.65	0.58	0.42			0.42
SR	SR1	0.879	0.85	0.28	0.72	0.60	0.88	0.73
	SR2		0.77	0.41	0.59			0.59
	SR3		0.79	0.38	0.62			0.62
	SR4		0.73	0.47	0.53			0.53
	SR5		0.73	0.47	0.53			0.54
WB	WB1	0.772	0.86	0.26	0.74	0.59	0.81	0.74
	WB2		0.77	0.41	0.59			0.59
	WB3		0.81	0.34	0.66			0.66
SP	SP1	0.780	0.88	0.22	0.77	0.58	0.80	0.78
	SP2		0.82	0.33	0.67			0.67
	SP3		0.55	0.70	0.30			0.30

Free parameters are estimated from the observed data and are expected to be nonzero. Conversely, fixed parameters are not estimated from the data and normally are set to zero. Besides, the structural model is evaluated by using several measures of goodness-of-fit indices such as the ratio of chi square to degree of freedom, normed fit index (NFI), relative fit index (RFI), comparative fit index (CFI), incremental fit index (IFI), root-mean-square error of approximation (RMSEA), and so on. Further details about these are in Jöreskog and Sörbo (1993) and Hair et al. (2014). After adequate overall fit is achieved, the measurement model is further evaluated for its reliability and validity (convergent and discriminant).

To Assess the Structural Model Validity

In the final step, the decision process assesses the validity of the structural model on the basis of the comparison between the structural model fit and CFA model fit. A critical issue regarding any SEM is the assessment of the overall model fit. Hair et al. (2014) recommend using at least one absolute index, one incremental index, and the model $\Delta\chi^2$ to evaluate the structural model validity. Therefore, the overall fit of the baseline model is assessed by using multiple goodness-of-fit (GOF) indices, including the ratio of chi square to degree of freedom, the RMSEA, the CFI, and the nonnormed fit index (NNFI). Moreover, the researcher should examine the statistical significance and direction of the relationships among constructs. The parameter estimates should be consistent with the hypotheses that reflected them before testing.

Data Analysis and Model Validation

Measurement Model (Confirmatory Factor Analyses)

Five hypotheses were constructed and tested by using SEM. According to Hair et al. (2014), the model should be simple, and more indicators need more samples. Therefore, to develop and test the structure, CFA was conducted for six latent constructs and their 20 indicators only. As shown in Table 3, all groupings in the hypothetical model have Cronbach's alpha values greater than 0.7. This indicates that the internal consistency and reliability of the hypothetical model are good. The communalities of all indicators are greater than 0.5, except HM3 ("We have knowledge of overall hazards in our project"), SC1 ("Safety climate in my current work place reduces occupational risk"), and SB3 ("How do you rate the safety budget in the project?"). Because the three indicators, HM3, SC1, and SB3, do not represent the same latent factor and their respective factor, loadings are higher than 0.50. This indicates that the measurement model is capable of reflecting the average of variation among the measured variables and item reliability in order (Hair et al. 2014). The R^2 values are the squared multiple coefficient from each of the separate regression analysis (between latent factors and their measures) in the measurement model. Based on this R^2, unique variance, communality, average variance extracted (AVE), and construct reliability (CR) can be calculated (Hair et al. 2014). In Table 3, the AVE of each construct is computed and found to be higher than 0.5, except hazard management, for which the AVE is 0.47, which is very close to 0.5 and thus acceptable. Table 3 also shows that the indicators of each construct converge or share a high proportion of variance in common.

As mentioned previously, at least three indicators per construct were taken; hence, the rank condition and order conditions are fulfilled by this model. Content validity is checked according to the discussions with safety professionals and existing literature. It provides evidence of uniqueness of a construct and checks the discriminant validity. Nomological validity and face validity have also been checked through discussions with professionals. The result shows that the given measurement model is valid and ready to be checked for its theory contribution by comparing the model against collected sample.

LISREL 8.8 output includes several fit indices that focus on the overall fit of the model. In Table 4, the overall model χ^2 is 463.22 with 155 degrees of freedom (DOF), and the p value is 0.00. The ratio of chi square to DOF (2.99) is within the permissible range; however, the p value is less than the significance error (0.05). It does not show that the observed covariance matrix matches the estimated covariance matrix within the sampling variance. Therefore, it needs to examine other fit statistics of the model. The goodness-of-fit index (GFI) value is 0.83 and thus is a good indicator; however, the RMSEA (0.09) is slightly greater than the permissible range (0.08). However, the range for the 90% confidence interval

Table 4. Estimation of Model Parameters

Goodness of fit and indices	Parameters	Permissible range	CFA	Hypothetical model	Revised model
Goodness of fit index	Chi square	As low as possible	463.22	460.5	451.8
	DOF	As high as possible	155	159	159
	Normed chi square (chi square/DOF)	Between 2 and 5	2.99	2.90	2.84
	P-value	>0.05 or 0.01	0.00	0.00	0.00
Absolute fit indices	GFI	0 to 1	0.83	0.83	0.83
	Adjusted GFI	>0.80	0.76	0.77	0.77
	RMSEA	<0.08	0.09	0.09	0.09
	90% confident interval for RMSEA	—	(0.08; 0.11)	(0.08; 0.10)	(0.08; 0.10)
	SRMR	<0.08 or 0.05	0.05	0.06	0.06
Incremental fit indices	NFI	>0.90 or 0.95	0.95	0.95	0.95
	TLI or NNFI	>0.90 or 0.95	0.96	0.96	0.96
	CFI	>0.90 or 0.95	0.97	0.96	0.97
	Relative noncentrally index (RNI)	>0.90 or 0.95	0.94	0.94	0.94
	IFI	>0.90 or 0.96	0.97	0.96	0.97
Parsimony fit indices	PNFI	>0.50	0.77	0.79	0.79
	PGFI	>0.50	0.61	0.63	0.63

for RMSEA is 0.08–0.10. Considering that the standardized root-mean-square residual (SRMR) value of 0.05 is in its permissible range, it is acceptable. In view of the aforementioned values, χ^2 indicates an acceptable fit for the CFA model.

In addition, all IFIs are equal or higher than their cutoff values, including CFI and Tucker Lewis index (TLI), as shown in Table 4. It reveals the acceptance of model complexity and sample size. No standardized residuals are found more than 4.0 and thus do not require any further improvement. Because of nonavailability of the largest modification indices (MIs) between indicators, this study does not require further modification of any relationship prevailing in the model. With this, all steps of confirmatory factor analysis are completed.

Path Model (Path Analysis)

For Step 5, the hypothesized theory was presented as the structural (path) model in the path diagram visually based on the five hypotheses as shown in Fig. 3(a). It was estimated and assessed according to the *LISREL 8.8* output as a hypothetical model, and its values of different parameters are shown in Table 4. All values are within the permissible range. In comparing the CFA and hypothetical models, it is observed that there has been a decrease of 2.72 in the chi-square value and an increase of four in the degree of freedom. Thus, there is visible improvement in the two models. Also, there is no major change in the path coefficients and loading estimates from the CFA model to the hypothetical model.

In the hypothetical model, the estimate between SR and WB was found to be 0.10 as shown in Fig. 3(a). Therefore, the path from SR to WB was deleted, and a new path was inserted between SR and SP in the revised model as shown in Fig. 3(b).

Table 4 compares the GOF measures for the "hypothetical model" and the "revised model." The resulting estimate is found to be 0.37 ($P < 0.001$) between SR and SP and 0.14 ($P < 0.001$) between SC and WB. Thus, there are improvements in both of these values. In addition, the overall fit exposes a χ^2 value of 451.80 with 159 degrees of freedom and a normed χ^2 value of 2.84. The TLI remains as it is, and the CFI slightly increased to 0.97. The GFI, RMSEA, SRMR, parsimony normed fit index (PNFI), and parsimony goodness-of-fit index (PGFI) values remain unchanged. The estimates of several paths have changed slightly from the original model as would be expected. All the relationships are found significant now as shown in Fig. 3(b).

Results and Discussion

As mentioned previously, big and self-performing construction firms were selected to study the interrelationships among five typical determinants of safety performance in the Indian construction industry. The safety management systems of these firms always make an effort to control these five determinants to improve the safety performance of projects.

Fig. 3(a) shows that safety rules and regulations do not influence much safe work behavior of workers. This is in line with the results of Patel and Jha (2014), which state that safety rules and procedures is one of the least significant determinants of safe work behavior. Therefore, there was not a strong evidence to accept Hypothesis 4. However, Mearns et al. (2003) investigated a significant correlation between rules and procedures and safety performance (accident rate) in offshore projects. Thus, it provides the evidence of a relationship between SR and SP of the project. In addition, modification index also suggests the relationship between SR and SP in the model. Therefore, a new hypothesis—SR are positively related to SP—is formulated and presented as shown in Fig. 3(b). Thus, on the basis of strong theoretical and empirical support, a new path between SR and SP has been considered and tested and is found to be a better model as shown in Fig. 3(b).

The model explores and endorses the existing relationship among all latent factors. It is interesting to note that SB influences WB more than the remaining constructs, which is supported by several researchers who already found a positive impact of safety investment on safety performance of building projects (Tang et al. 1997; Feng 2013). The relationship between HM and WB reveals that the practice of identifying and assessing hazards leads to safer work behavior among employees and workers. Thomas et al. (2005) also obtained higher relative ranking of project management commitment and hazard management among the main factors of project-related safety performance evaluations (SPE). In addition, Teo et al. (2006) found that identifying hazardous and dangerous activities influence site safety. The finding of this study is consistent with the findings of the previous research that effective HM improves the work behavior of workers and employees and thus the safety performance in construction sites (Mohamed 2002; Feng 2013). Mohamed (2002) studied the relationships between the safety climate and self-reported safe work behavior in construction site environments using SEM. Cooper and Phillips (2004) found an empirical link between safety climate and actual safe behavior. Johnson (2007) studied predictive relationships between safety climate and safety outcomes by using analysis of correlation coefficient and SEM. They found that safety climate could serve an effective predictor of safe behavior and injury severity (lost work days). Pousette et al. (2008) found that safety climate could also be an important predictor of safety behavior of construction workers.

Safety rules and regulations play a major role in the managing of safety levels in organizations (Cox and Cheyne 2000; Mearns et al. 2003). However, this study reveals that SR influence the safety performance of the project; however, there may be an issue of effective implementation of safety rules and regulations in controlling the safe work behavior of workers and employees. It indicates that existing safety rules and regulations should be revised, keeping in mind the safe work behavior of workers and employees and the safety performance.

The model also supports the significant positive relationship between the safe work behavior of workers and employees and the safety performance at the construction project (Cooper and Philips 1994; Mohamed 2002). The results of this study have also been discussed with various experts associated with safety management system. They have endorsed the outcomes of this study with their field practice. The results have shown a reasonably good overall model fit, and the hypothesized relationships are found to be supported. Thus, these findings reveal and endorse the validity and reliability of the structural model too.

Summary and Conclusions

The safety system is very complex because it includes many interrelated latent factors. Therefore, to investigate the relationship-based determinants of safety performance, this study selects five important determinants of safety performance and their hypothesized interrelationships among them on the basis of the existing literature. Confirmatory factor analysis has been conducted to test the constructs' validity and the items' reliability of the model. Afterward, the structure was formulated according to constructed hypotheses, and their path analysis presents the overall fit of the model after examining their statistical parameters by using *LISREL 8.8*.

In the safety system, some latent factors may be influenced by their regional culture and economic conditions. As mentioned in previous sections, this study found a significant positive relationship between safety performance and safe work behavior as would be expected according to the existing literature. In addition, safety climate, hazard management, and safety budget influence the safe work behavior of employees. However, existing safety rules and regulations do not seem much effective in controlling the work behavior of employees; nonetheless, they are positively associated with the safety performance of the project. In this regard, this study reveals that the existing safety rules and regulations are not capable of improving the safe work behavior of workers. Therefore, safety rules and regulations should include and emphasize provisions such as regular training to workers and employees to ensure their safe work behavior. However, allocating a sufficient portion of the budget for safety concerns is directly associated with safe work behavior of employees.

According to Hair et al. (2014), the good empirical fit does not prove that the given model is the only legitimate structure, and a researcher may revise the model by adding or deleting latent factors and their indicators with theoretical evidence. The indicators HM3 ("We have knowledge of overall hazards in our project"), SC1 ("Safety climate in my current work place reduces occupational risk"), and SB3 ("How do you rate the safety budget in the project?") should be reconstructed or replaced to get improvement in their loadings. However, this model possesses sufficient theoretical evidence with empirical analysis. It shows the overall fit of the model. The study faced certain constraints such as unavailability of exact figures for safety budget and accident statistics and low implementations of rules and regulations in construction projects. Further study could be organized to investigate the direct and mediating effects of other factors such as project nature, human error, competence of employees, and so forth on safety performance of construction projects. Partial least squares (PLS) may be used as an alternative to the SEM.

In a nut shell, this study determined five important determinants of safety performance and presented the general form of the SEM, which consists of a measurement model (Fig. 3). This measurement model specifies how the hypothesized constructs (five determinants of safety performance) are measured in terms of the observed indicators (e.g., HM1, HM2, and SC1). Subsequently, structural model explores the causal relationships [Fig. 3(b)] between these validated constructs (determinants) and tests the hypothesized effects. The SEM was verified by evaluating its appropriateness through empirical analysis, and it was also revised accordingly. The identified and verified interrelationships in the model show the mechanism of influence among determinants of safety performance.

Managerial Implications of the Study

Safety management is an interdisciplinary and complicated subject. As mentioned previously, there is a challenge to manage safety in the Indian construction industry. In such circumstances, client and contractors may generally hesitate to allocate a sufficient portion of the budget of construction projects to improving safety performance because of a lack of confidence in positive results. This study attempts to remove this illusion and inspires top management and clients to allocate a sufficient safety budget to construction projects to control and improve safe work behavior of workers and safety performance. Similarly, policy makers should focus on safe work behavior of workers. Besides, safety climate and hazard management should also be improved because they positively influence safe work behavior of workers.

In brief, this study presents a holistic framework of safety system in construction projects. Based on this framework, this study examined some existing relationships between SC, HM, SR, WB, and SP in regard to the Indian construction sector. By developing the SEM and using *LISREL 8.8*, the coefficient of determination found for each latent variable shows their effects on outcomes of safety system. It discovered some new relationships, for example, between safety budget and work behavior, and safety rules and regulations and safety performance, that were not fathomed very well previously. The finding will draw new attention while framing safety rules and regulations and making provisions of safety budget in construction projects. It will lead to better decisions and help manage safety effectively in construction projects.

In short, the SEM and the six determinants (latent factors) describe and validate a part of the developed framework. It will be helpful to measure and improve the safety system in construction projects. The development of a framework, the use of MLE coupled with popular software in formulation of research method, and the exploration of the importance of safety budget are the main contributions of this study.

References

Aksorn, T., and Hadikusumo, B. H. W. (2008). "Measuring effectiveness of safety programmes in the Thai construction industry." *Constr. Manage. Econ.*, 26(4), 409–421.

Benjamin, O. A. (2008). *Fundamental principles of occupational health and safety*, 2nd Ed., International Labour Organization, Geneva.
BIS (Bureau of Indian Standards). (1998). "Indian standard- code of practice on occupational safety and health audit." *IS 14489:1998*, New Delhi, India.
Brown, R. L., and Holmes, H. (1986). "The use of a factor analytic procedure for assessing the validity of an employee safety climate model." *Accid. Anal. Prev.*, 18(6), 455–470.
Carter, G., and Smith, S. (2006). "Safety hazard identification on construction projects." *J. Constr. Eng. Manage.*, 10.1061/(ASCE)0733-9364(2006)132:2(197), 197–205.
Chen, Y., Zhang, Y., Liu, J., and Mo, P. (2012). "Interrelationships among critical success factors of construction projects based on the structural equation model." *J. Manage. Eng.*, 10.1061/(ASCE)ME.1943-5479.0000104, 243–251.
Choudhry, R. M., Fang, D. P., and Mohamed, S. (2007). "The nature of safety culture: A survey of the state of the art." *Saf. Sci.*, 45(10), 993–1012.
Cooper, M. D., and Philips, R. A. (1994). "Validation of a safety climate measure." *Proc., Annual Occupational Psychology Conf.*, British Psychological Society, Birmingham, U.K.
Cooper, M. D., and Phillips, R. A. (2004). "Exploratory analysis of the safety climate and safety behavior relationship." *J. Saf. Res.*, 35(5), 497–512.
Cox, S. J., and Cheyne, A. J. T. (2000). "Assessing safety culture in offshore environments." *Saf. Sci.*, 34(1), 111–129.
DeDobbeleer, N., and Beland, F. (1991). "A safety climate measure for construction sites." *J. Saf. Res.*, 22(2), 97–103.
El-Mashaleh, M. S., Rababeh, S. M., and Hyari, K. H. (2010). "Utilizing data envelopment analysis to benchmark safety performance of construction contractors." *Int. J. Proj. Manage.*, 28(1), 61–67.
Fang, D., Huang, X., and Hinze, J. (2004). "Benchmarking studies on construction safety management in China." *J. Constr. Eng. Manage.*, 10.1061/(ASCE)0733-9364(2004)130:3(424), 424–432.
Fang, D., Wu, C., and Wu, H. (2015). "Impact of the supervisor on worker safety behavior in construction projects." *J. Manage. Eng.*, 10.1061/(ASCE)ME.1943-5479.0000355, 04015001.
Feng, Y. (2013). "Effect of safety investments on safety performance of building projects." Ph.D. thesis, National Univ. of Singapore (NUS), Singapore.
Fernandez-Muniz, M., Montres-Peon, J. M., and Vazquez-Ordas, C. J. (2007). "Safety management system: development and validation of a multidimensional scale." *J. Loss Prev. Process. Ind.*, 20(1), 52–68.
Fornell, C., and Larcker, D. F. (1981). "Evaluating structural equation models with unobservable variables and measurement errors." *J. Market. Res.*, 18(1), 39–50.
Hair, J., Anderson, R., Babin, B. J., and Black, W. (2014). *Multivariate data analysis*, 7th Ed., Pearson Education, London.
Hinze, J., and Godfrey, R. (2003). "An evaluation of safety performance measures for construction projects." *J. Constr. Res.*, 4(1), 5–15.
Hinze, J., Thurman, S., and Wehle, A. (2013). "Leading indicators of construction safety performance." *Saf. Sci.*, 51(1), 23–28.
Hinze, J., and Wilson, G. (1999). "Moving toward a zero injury objective." *J. Constr. Eng. Manage.*, 10.1061/(ASCE)0733-9364(2000)126:5(399), 399–403.
Hinze, J. W. (2000). *Construction safety*, Prentice-Hall, NJ.
HSE (Health and Safety Executive). (2001). "Summary guide to safety climate tools." *Offshore Technology Rep. No. 1999/063*, London.
ILO (International Labor Organization). (2005). "Facts on safety work." ⟨http://www.ilo.org/wcmsp5/groups/public/—dgreports/—dcomm/documents/publication/wcms_067574.pdf⟩ (Oct. 31, 2011).
Imriyas, K., Low, S., Teo, A., and Chan, S. (2008). "Premium-rating model for workers' compensation insurance in construction." *J. Constr. Eng. Manage.*, 10.1061/(ASCE)0733-9364(2008)134:8(601), 601–617.
Ingalls, T. S. (1999). "Using scorecards to measure safety performance." *Prof. Saf.*, 8(5), 23–28.
Jaselisks, E., Anderson, S., and Russell, J. (1996). "Strategies for achieving excellence in construction safety performance." *J. Constr. Eng. Manage.*, 10.1061/(ASCE)0733-9364(1996)122:1(61), 61–70.
Johnson, S. E. (2007). "The predictive validation of safety climate." *J. Saf. Res.*, 38(5), 511–521.
Jöreskog, K., and Sörbom, D. (1993). *LISREL 8: Structural equation modeling with the SIMPLIS command language*, Scientific Software International, Chicago.
Khanzode, V. V., Maiti, J., and Ray, P. K. (2012). "Occupational injury and accident research: A comprehensive review." *Saf. Sci.*, 50(5), 1355–1367.
Kline, R. B. (1998). *Principles and practice of structural equation modeling*, 3rd Ed., Guilford, New York.
Koehn, E., and Musser, K. (1983). "OSHA regulations effects on construction." *J. Constr. Eng. Manage.*, 10.1061/(ASCE)0733-9364(1983)109:2(233), 233–244.
Li, R. Y. M., and Poon, S. W. (2013). *Construction safety*, Springer, London.
LISREL version 8.8 [Computer software]. Scientific Software International, Chicago.
Mahalingam, A., and Levitt, R. E. (2007). "Safety issues on global projects." *J. Constr. Eng. Manage.*, 10.1061/(ASCE)0733-9364(2007)133:7(506), 506–516.
Manuele, F. A. (2010). "Acceptable risk: Time for SHE professionals to adopt the concept." *Prof. Saf.*, 5(55), 30–38.
Mearns, K. J., Whitaker, S. M., and Flin, R. (2003). "Safety climate, safety management practice and safety performance in offshore environments." *J. Constr. Steel Res.*, 41(8), 641–680.
Mohamed, S. (2002). "Safety climate in construction site environments." *J. Constr. Eng. Manage.*, 10.1061/(ASCE)0733-9364(2002)128:5(375), 375–384.
Molenaar, K. R., Park, J-II., and Washington, S. (2009). "Framework for measuring corporate safety culture and its impact on construction safety performance."*J. Constr. Eng. Manage.*, 10.1061/(ASCE)0733-9364(2009)135:6(488), 488–496.
Neal, A., and Griffin, M. A. (2006). "A study of the lagged relationships among safety climate, safety motivation, safety behaviour and accidents at individual and group levels." *J. Appl. Psychol.*, 91(4), 946–953.
Ng, S. T., Cheng, K. P., and Skitmore, R. M. (2005). " A framework for evaluating the safety performance of construction contractors." *Build. Environ.*, 40(10), 1347–1355.
Ozorhon, B., Arditi, D., Dikmen, I., and Birgonul, M. (2010). "Performance of international joint ventures in construction." *J. Manage. Eng.*, 10.1061/(ASCE)ME.1943-5479.0000022, 209–222.
Patel, D. A., and Jha, K. N. (2014). "Neural network approach for safety climate prediction." *J. Manage. Eng.*, 10.1061/(ASCE)ME.1943-5479.0000348, 05014027.
Patel, D. A., and Jha, K. N. (2015). "A framework to evaluate construction project hazard using the possibility approach." *J. Constr. Eng. Manage.*, in press.
Patel, D. A. (2015). "Estimating the number of fatal accidents and investigating the determinants of safety performance in Indian construction." Ph.D. thesis, Indian Institute of Technology Delhi, New Delhi, India.
Paul, P. S., and Maiti, J. (2007). "The role of behavioral factors on safety management in underground mines." *Saf. Sci.*, 45(4), 449–471.
Pousette, A., Larsson, S., and Torner, M. (2008). "Safety climate cross-validation, strength and prediction of safety behavior." *Saf. Sci.*, 46(3), 398–404.
Reason, J. (1997). *Managing the risks of organizational accidents*, Ashgate, Hampshire, U.K.
Rowlinson, S. (2004). *Construction safety management systems*, Spon, London.
Sawacha, E., Naoum, S., and Fong, D. (1999). "Factors affecting performance on construction sites." *Int. J. Project Manage.*, 17(5), 309–315.
Schumacker, R., and Lomax, R. (2004). *A beginner's guide to structural equation modeling*, 2nd Ed., Lawrence Erlbaum Associates, Mahwah, NJ.
Siriruttanapruk, S., and Anuntakulnathi, P. (2004). "Occupational health and safety situation and research priority in Thailand." *Ind. Health*, 42(2), 135–140.
Tabish, S. Z. S. (2011). "Critical success factors and fair performance in public construction projects." Ph.D. thesis, Indian Institute of Technology Delhi, New Delhi, India.

Tabish, S. Z. S., and Jha, K. N. (2012). "Success traits for a construction project." *J. Constr. Eng. Manage.*, 10.1061/(ASCE)CO.1943-7862.0000538, 1131–1138.

Tang, S. L., Lee, H. K., and Wong, K. (1997). "Safety cost optimization of building projects in Hong Kong." *Constr. Manage. Econ.*, 15(2), 177–186.

Teo, E. A. L., and Ling, F. Y. Y. (2006). "Developing a model to measure the effectiveness of safety management systems of construction sites." *Build. Environ.*, 41(11), 1584–1592.

Thomas, N. S., Cheng, K. P., and Martin, S. R. (2005). "A framework for evaluating the safety performance of construction contractors." *Build. Environ.*, 40(10), 1347–1355.

Wiegmann, D. A., Hui, Z., Thaden, T. L. V., Sharma, G., and Gibbons, A. M. (2004). "Safety culture: An integrative review." *Int. J. Aviat. Psychol.*, 14(2), 117–134.

Wu, T. C., Chen, C. H., and Li, C. C. (2008). "A correlation among safety leadership, safety culture and safety performance." *J. Loss prev. Process Ind.*, 21(3), 307–318.

Xiong, B., and Skitmore, M. (2015) "Review: A critical review of structural equation modeling applications in construction research." *Autom. Constr.*, 49(1), 59–70.

Zhou, Z., Goh, Y. M., and Li, Q. (2015). "Overview and analysis of safety management studies in the construction industry." *Saf. Sci.*, 72, 337–350.

Zohar, D. (1980). "Safety climate in industrial organizations: Theoretical and applied implications." *J. Appl. Psych.*, 65(4), 96–102.

Zou, P. (2011). "Fostering a strong construction safety culture." *Leadersh. Manage. Eng.*, 10.1061/(ASCE)LM.1943-5630.0000093, 11–22.