Iranian J Publ Health, Vol. 43, No.8, Aug 2014, pp. 1099-1106

Original Article

Structural Modeling of Safety Performance in Construction Industry

*Yahya KHOSRAVI [1],*Hassan ASILIAN-MAHABADI [1], Ebrahim HAJIZADEH [2], Narmin HASSANZADEH-RANGI [3], Amir H. BEHZADAN [4]*

1. Dept. of Occupational Health Engineering, Faculty of Medical Sciences, Tarbiat Modares University, Tehran, Iran
2. Dept. of Biostatistics, Faculty of Medical Sciences, Tarbiat Modares University, Tehran, Iran
3. Dept. of Occupational Health Engineering, Shahid Beheshti University of Medical Sciences, Tehran, Iran
4. Dept. of Civil, Environmental, and Construction Engineering, University of Central Florida, Orlando, FL, USA

***Corresponding Author:** Tel: +98 21 82883590 Email: asilia_h@modares.ac.ir

(Received 10 Mar 2014; accepted 16 Jun 2014)

Abstract

Background: With rapid economic development and industrialization, the construction industry continues to rank among the most hazardous industries in the world. Therefore, construction safety is always a significant concern for both practitioners and researchers. The objective of this study was to create a structural modeling of components that influence the safety performance in construction projects.

Methods: We followed a two-stage Structural Equation Model based on a questionnaire study (n=230). In the first stage, we applied the Structural Equation Model to the proposed model to test the validity of the observed variables of each latent variable. In the next stage, we modified the proposed model. The LISREL 8.8 software was used to conduct the analysis of the structural model.

Results: A good-fit structural model (Goodness of Fit Index=0.92; Root Mean Square Residual=0.04; Root Mean Square Error of Approximation=0.04; Comparative Fit Index=0.98; Normalized Fit Index=0.96) indicated that social and organizational constructs influence safety performance via the general component of the safety climate.

Conclusion: The new structural model can be used to provide better understanding of the links between safety performance indicators and contributing components, and make stronger recommendations for effective intervention in construction projects.

Keywords: Safety performance, Structural equation modeling, Construction projects

Introduction

With rapid economic development and industrialization, the construction industry continues to rank among the most hazardous industries in the world (1). Within the construction industry, the risk of a fatality is five times more than in manufacturing, whilst the risk of a major injury is two and a half times higher (2).

Construction safety is always a significant concern for both practitioners and researchers (3). One reason may be that the project management does not know how to evaluate the safety performance of a construction project. It is imperative that in order to effectively manage the safety management system, a composite performance evaluation system consisting of measurable and achievable indicators in many facets of safety management is required (4).

According to previous studies (5-7), safety performance indicators can be divided into two types: passive indicators and active indicators. Passive indicators refer to both before-the-accident and after-the-accident indicators. Before-the-accident indictors include unsafe behaviors and unsafe conditions. After-the-accident indicators refer to historical parameters such as near-miss rate, accident rate, and number of lost days. There are some limitations and shortcomings of passive performance measurements when used in occupational safety and health management, such as insufficient descriptive data about injuries (5). Active safety performance involves implementing proactive practices ranging from safety inspections and safety trainings, to implementation of effective safety supervision and management. In addition, review of the construction safety performance literature introduces many different constructs compromising a variety of the contributing factors that affect the construction safety performance. Among these, for example, previous studies focused on safety climate and its dimensions (8-12).

While the safety climate-safety performance relationship is well documented (13-15), the mechanism of this relationship is not clearly understood, especially in construction projects. Wu et al. (2008) stated that although many studies reported that the higher the score of a safety climate, the better the safety performance, there has not been much discussion about the causality of safety climates (16).

Today, further research is necessary to develop new applied theories, and make stronger recommendations (1). In addition, more work is needed to integrate different safety constructs and contributing components in a holistic framework. Only through such integrated framework can a common understanding of safety performance be achieved. Considering all these components, the goal of this study was the structural modeling of components affecting safety performance on construction projects.

Materials & Methods

Procedure and participants

We conducted a questionnaire study based on a previous extracted structure (17). In total, 230 participants with a mean age of 48.4 years (SD=9.5) took part in the survey. The participants were a random sample from different jobs, work sites, and projects in different geographical and cultural areas in Iran. All participants were construction employees who were potentially exposed to occupational hazards.

Proposed structural model and hypotheses

As shown in Table 1, the observed variables were interpreted according to the findings of our previous qualitative research (17), as follows: (a) General safety climate (SCFs); (b) Individual features (IFs); (c) and General safety performance (SPs). In this study, we suggested the following hypotheses to represent the relations between these components:

Hypothesis 1 (H1). The SCFs have a significant effect on the IFs.

Hypothesis 2 (H2). The SCFs have a significant effect on the SPs.

Hypothesis 3 (H3).The IFs have a significant effect on the SPs.

These hypotheses in the form of the proposed structural model represent relations between latent variables, as illustrated in Fig. 1.

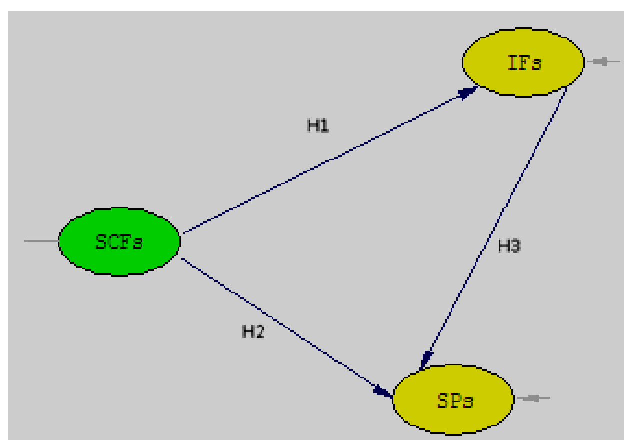

Fig. 1: Proposed structural model

Data analysis

Structural equation modeling (SEM) is a comprehensive statistical approach to testing hypotheses about relations between observed and latent variables.

Table 1: Descriptions of the latent and observed components adopted from Khosravi et al. (17)

Component (Features)	Descriptions
Individual features (IFs)	
Safety motivation and prohibition (IF1)	Refers to subthemes related the arousal and direction process to a safe or unsafe behavior. such as "*Risk taking to become a key person in a contractor*"
Safety attitude and belief (IF2)	Refers to subthemes related to an internal feeling toward safety issues and is expressed through words and behavior. such as "*Accident as a chancy phenomena*"
Safety values (IF3)	Refers to subthemes related to degree of the worth or importance a person attaches to safety issues. Such as "*Safety Last as a core value*"
General safety performance (SPFs)	
Psychological conditions (SP1)	Refers to subthemes related to stressful site conditions resulting from project management, which might lead to workers' exhausting, sleep deprivation, depressive symptoms, mental distraction or job dissatisfaction. Such as "*hurry to finish the work*"
Physical conditions (SP2)	Refers to subthemes related to unsafe site conditions resulting from project management, which might lead to the more exposure of workers with hazards. Such as "*using old and defective machines*"
Unsafe behavior (SP3)	Refers to subthemes related to non- and intentional deviations from the safety regulations and procedures. Such as "*I leave my PPEs because these devices are annoying*"
Accident and near miss (SP4)	Refers to number of the accident and near miss.
General safety climate (SCFs)	
Client safety climate (SCF1)	Refers to subthemes related to perceived client management attitudes toward safety. Such as "*contractors are under client time pressure*"
Contractor competency (SCF2)	Refers to subthemes related to the combination of skills, experience and knowledge that contractors must be have to meet the contractual requirements. Such as "*contractors prefer to part-time recruitment*"
Safety supervision and management (SCF3)	Refers to subthemes related to the combination of regulation, procedures and practices to meet the safety goals and policies. Such as "*There are significant gaps between procedures and work practices*"
Contract management (SCF4)	Refers to subthemes related to the process of systematically and efficiently managing contract creation, execution and analysis for maximizing operational and financial performance and minimizing risk. Such as "*There is no specific resource allocation for safety*"
Social safety climate (SCF5)	Refers to subthemes related to perceived society attitudes toward safety such as "*an 'unsafe worker' is an 'unsafe driver'* "
Contractor safety climate (SCF6)	Refers to subthemes related to perceived contractor management attitudes toward safety. Such as "*Take shortcut for achieving a higher profit*"

The SEM is more flexible and comprehensive than any other approaches (such as correlation, multiple regression, and ANOVA), providing means of controlling not only for extraneous or confounding variables but for measurement errors as well (18).

We followed a two-stage SEM according to Anderson and Gerbing (1988) to test the hypotheses (19). First, we conducted the SEM on the proposed model to test the validity of the observed variables of each latent variable. In the next stage, we modified the structural model in the SEM. The model modification follows the estimation of a model that resulted in unfavorable indices of fit (18). To apply the SEM, the LISREL 8.8 software was used to conduct the analysis of structural model (20).

In order to assess the fit of the models, the following common goodness-of-fit indices were used: Goodness of Fit Index (GFI), Adjusted Goodness of Fit Index (AGFI), Parsimony Goodness of Fit Index (PGFI), Root Mean Square Residual (SRMR), Root Mean Square Error of Approximation (RMSEA), Comparative Fit Index (CFI), Incremental Fit Index (IFI), Relative Fit Index (RFI), Normalized Fit Index (NFI), Non-Normalized Fit Index (NNFI), Parsimony Normalized Fit Index (PNFI), and χ^2/df(21).

Results

Table 2 compares the goodness-of-fit indices of the alternative models with recommended values. The proposed structural model A1 (Fig. 2) indicates a good fit (GFI=0.94; SRMR=0.05; RMSEA=0.06; CFI=0.98; NFI=0.96; χ^2/df=1.85). However, a two-stage modification was conducted on the proposed structural model to obtain a better goodness-of-fit. As shown in Table 2, all indices of the modified model (Fig. 3) indicated a better fit to the data (GFI=0.92; SRMR=0.04; RMSEA=0.04; CFI=0.98; NFI=0.96; χ^2/df=1.78).

Hypothesis test, as illustrated in Figure 2, indicated that the SCFs predict the IFs (standardized path coefficient=0.71; *t*-Value=8.53) and the SPs (standardized path coefficient=0.84; *t*-Value=5.30), which support both hypotheses 1 and 2. However, the IFs did not exhibit to have a significant effect on the SPs (standardized path coefficient=-0.07; *t*-Value=-0.63), and therefore, hypothesis 3 is rejected.

Based on the modified model in Figure 3, it appears that the client safety climate (SCF1) has the highest association (standardized path coefficient=0.82) with the general safety climate (SCFs). Among the main individual features, the safety motivation and prohibition (IF1) and safety attitude and belief (IF2) had the greatest association (standardized path coefficient=0.83) with the individual features (IFs). While psychological condition (SP1) has the highest association (standardized path coefficient=0.73) with the general safety performance (SPs), the accident and near-miss engagement (SP4) has a week but significant association (standardized path coefficient=0.20) with the general safety performance (SPs).

Table 2: Comparison of the goodness-of-fit indices of alternative structural models

Fit indices	Recommended values*	Proposed structural model A1	Modified structural model A2
GFI	>0.90	0.94	0.92
AGFI	>0.90	0.91	0.91
PGFI	>0.50	0.64	0.62
SRMR	<0.05	0.04	0.04
RMSEA	<0.10	0.06	0.06
CFI	>0.90	0.98	0.98
IFI	>0.90	0.98	0.98
RFI	>0.90	0.95	0.95
NFI	>0.90	0.96	0.96
NNFI	>0.90	0.98	0.98
PNFI	>0.50	0.76	0.75
χ^2/df	≤3	1.85	1.78

* Reference: Jöreskog and Sörbom, 1993

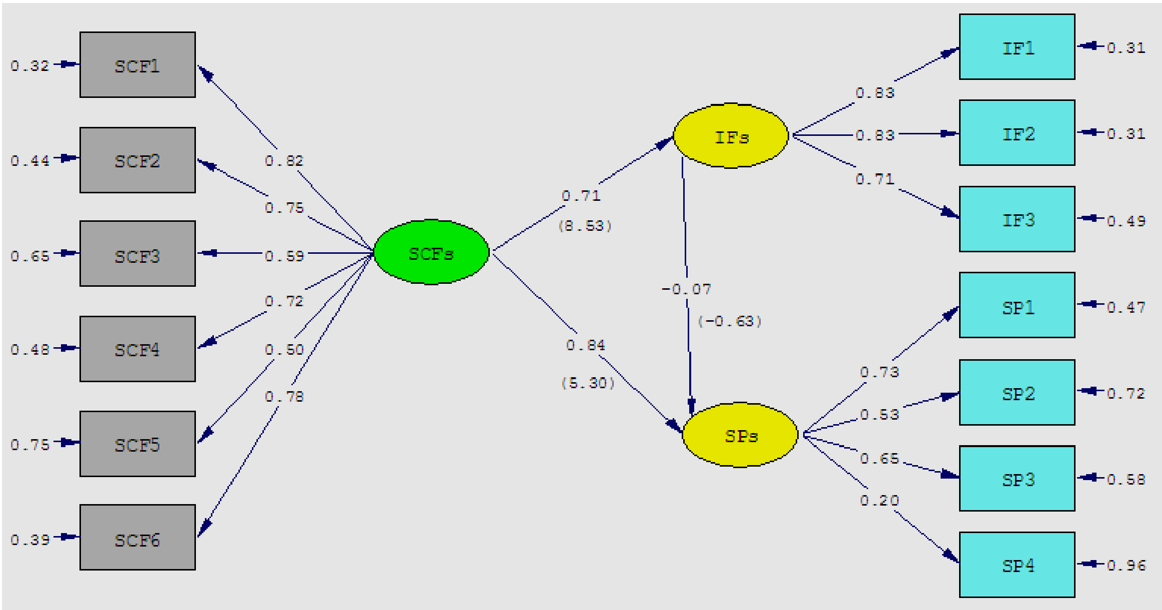

Fig. 2: Proposed structural model (A1) with standardized path coefficients (t-Value in parentheses: t-Value above 1.96 shows significant at 95% confidence level)

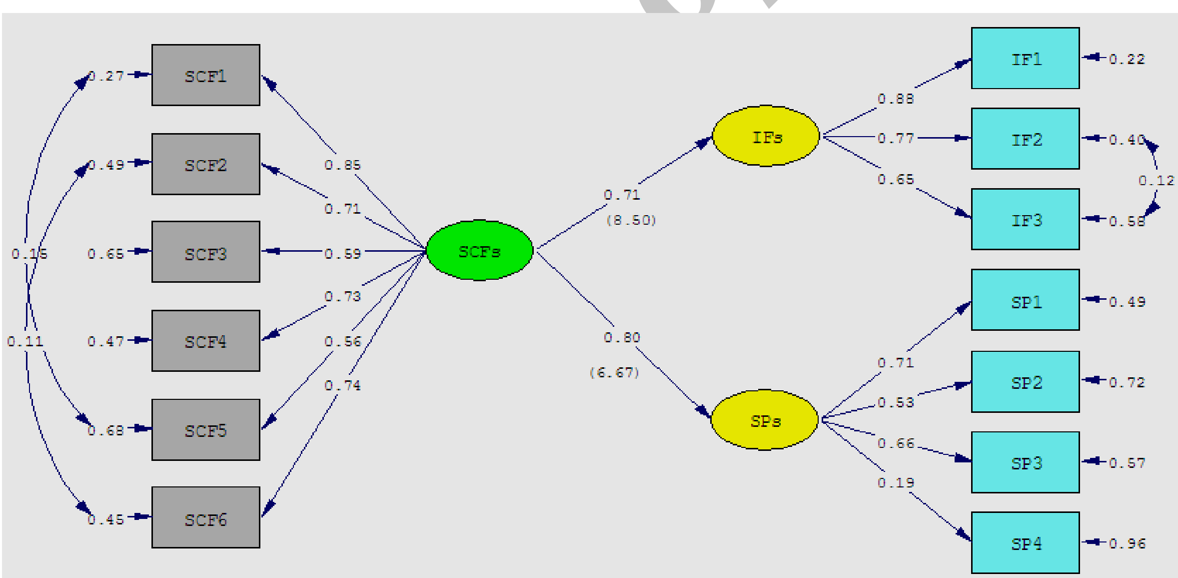

Fig. 3: Modified structural model (A2) with standardized path coefficients (t-Value in parentheses: t-Value above 1.96 shows significant at 95% confidence level)

Discussion

Based on the presented study, some social and organizational constructs share their influence on safety performance via the general component of safety climate. The new structural model shows that the general safety climate predicts individual features and general safety performance. A theoretical implication of this finding is the integration of the indicators and the contributing com-

ponents that influence safety performance, into a holistic model.
The client safety climate is more strongly related to the general safety climate. This finding is partially in line with previous findings that safety climate is one of the most important component affecting safety performance and accident (11, 14, 15, 22-24). Results of this work also confirmed the findings of previous studies that highlighted the importance of distal factors such as organization, economic, social, and political pressures that may contribute to reducing unsafe behaviors and accidents through improving construction operations, site conditions, and individual features as proximal factors (1, 25).
In this study, it was found that the association among the general safety performance with the unsafe behavior and psychological condition tended to be higher than that with the near-miss or accident engagement. A number of studies have found that the historical or retrospective safety indicators such as the injury or accident rate are generally regarded as less reliable to measure workplace safety in the construction industry (26). Most practitioners and researchers in this field have only focused on accident records as data source. Therefore, their findings are likely to be subjected to underestimation error.
Contrary to expectations, the most interesting finding of this study was that the unsafe behavior had more association with unsafe condition than individual safety features. This finding alters the widely accepted view that in construction projects, an individual's characteristics are key components in accident causation and control (27-29). In order to implement effective interventions, more focus on psychological and physical conditions is therefore suggested. Unsafe physical conditions include the lack of appropriate safety equipment, insufficient lighting, poor housekeeping, and working in bad weather conditions. Unsafe psychological conditions include the lack of welfare facilities and work group interaction, work pressure, and mental workload (17). The findings of this research seem to be consistent with previous work which found that unsafe behaviors are conflicting stimuli due to the conflict between immediate benefits and future potential costs (30). Physical or psychological conditions can weigh on one side of the conflict and lighten the other, thereby reducing or increasing the rate of safety violations. In addition, the general safety climate influences the physical or psychological conditions. If the unsafe conditions are not known or not properly perceived, workers may engage in human error, another type of unsafe behavior.

Conclusion

This study provided a new good fit structural model that suggests that some social and organizational components share their influence on safety performance via the general component of safety climate. The new structural model, which integrated the pervious constructs, can be used to provide better understanding of the links between safety performance indicators and contributing components, and make stronger recommendations for effective intervention in construction projects.

Ethical considerations

Ethical issues (including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy) have been completely observed by the authors.

Acknowledgements

This study was financially supported by the MAPNA Group. Any opinions, findings, conclusions, and recommendations expressed in this paper are those of the authors and do not necessarily reflect the views of the MAPNA Group. The authors declare that there is no conflict of interests.

References

1. Khosravi Y, Asilian-Mahabadi H, Hajizadeh E, Hassanzadeh-Rangi N, Bastani H,Behzadan AH (2014). Factors Influencing Unsafe

Behaviors and Accidents on Construction Sites: A Review. *Int J Occup Saf Ergon,* 20: 111-125.

2. Sawacha E, Naoum S,Fong D (1999). Factors affecting safety performance on construction sites. *Int J Proj Manag,* 17:309-315.
3. Cigularov KP, Chen PY,Rosecrance J (2010). The effects of error management climate and safety communication on safety: A multi-level study. *Accid Anal Prev,* 42:1498-1506.
4. Chang JI,Liang C-L (2009). Performance evaluation of process safety management systems of paint manufacturing facilities. *J Loss Prevent Proc,* 22:398-402.
5. Hsu IY, Su T-S, Kao C-S, Shu Y-L, Lin P-R,Tseng J-M (2012). Analysis of business safety performance by structural equation models. *Saf Sci,* 50:1-11.
6. Jones S, Kirchsteiger C,Bjerke W (1999). The importance of near miss reporting to further improve safety performance. *J Loss Prevent Proc,* 12:59-67.
7. Fang D, Xie F, Huang X,Li H (2004). Factor analysis-based studies on construction workplace safety management in China. *Int J Proj Manag,* 22:43-49.
8. Dedobbeleer N,Béland F (1991). A safety climate measure for construction sites. *J saf Res,* 22:97-103.
9. Mohamed S (2002). Safety climate in construction site environments. *J Cons Eng Manag,* 128:375-384.
10. Gillen M, Baltz D, Gassel M, Kirsch L,Vaccaro D (2002). Perceived safety climate, job demands, and coworker support among union and nonunion injured construction workers. *J saf Res,* 33:33-51.
11. Glendon AI,Litherland DK (2001). Safety climate factors, group differences and safety behaviour in road construction. *Saf Sci,* 39:157-188.
12. Siu O-l, Phillips DR,Leung T-w (2004). Safety climate and safety performance among construction workers in Hong Kong: The role of psychological strains as mediators. *Accid Anal Prev,* 36:359-366.
13. Gittleman JL, Gardner PC, Haile E, Sampson JM, Cigularov KP, Ermann ED, Stafford P,Chen PY (2010). [Case Study] CityCenter and Cosmopolitan Construction Projects, Las Vegas, Nevada: Lessons learned from the use of multiple sources and mixed methods in a safety needs assessment. *J Safety Res,* 41:263-281.
14. Pousette A, Larsson S,Törner M (2008). Safety climate cross-validation, strength and prediction of safety behaviour. *Saf Sci,* 46:398-404.
15. Zhou Q, Fang D,Wang X (2008). A method to identify strategies for the improvement of human safety behavior by considering safety climate and personal experience. *Saf Sci,* 46:1406-1419.
16. Wu T-C, Chen C-H,Li C-C (2008). A correlation among safety leadership, safety climate and safety performance. *J Loss Prevent Proc,* 21:307-318.
17. Khosravi Y, Asilian-Mahabadi H, Hajizadeh E, Hassanzadeh-Rangi N, Bastani H, Khavanin A,Mortazavi S (2014). Modeling the factors affecting unsafe behavior in the construction industry from safety supervisors' perspective. *J Res Health Sci,* 14:29.
18. Hoyle RH (1995). *Structural equation modeling: Concepts, issues, and applications*. ed. Sage.
19. Anderson JC,Gerbing DW (1988). Structural equation modeling in practice: A review and recommended two-step approach. *Psychol Bull,* 103:411.
20. Joreskog K,Sorbom D (2006). LISREL 8.8. *Lincolnwood, IL: Scientific Software Inc.*
21. Jöreskog KG,Sörbom D (1993). *Lisrel 8: Structured equation modeling with the Simplis command language*. ed. Scientific Software International.
22. Abbe OO, Harvey CM, Ikuma LH,Aghazadeh F (2011). Modeling the relationship between occupational stressors, psychosocial/physical symptoms and injuries in the Construction Industry. *IntJ Indus Ergon,* 41:106-117.
23. Goldenhar LM, Williams LJ,Swanson NG (2003). Modelling relationships between job stressors and injury and near-miss outcomes for construction labourers. *Work & Stress,* 17:218-240.
24. Meliá JL, Mearns K, Silva SA,Lima ML (2008). Safety climate responses and the perceived risk of accidents in the construction industry. *Saf Sci,* 46:949-958.
25. Suraji A, Duff A,Peckitt S (2001). Development of Causal Model of Construction Accident Causation. *J Cons Eng Manag,* 127:337-344.
26. Fang DP, Xie F, Huang XY,Li H (2004). Factor analysis-based studies on construction

workplace safety management in China. *Int J Proj Manag,* 22:43-49.

27. Törner M,Pousette A (2009). Safety in construction – a comprehensive description of the characteristics of high safety standards in construction work, from the combined perspective of supervisors and experienced workers. *J Saf Res,* 40:399-409.
28. Aksorn T,Hadikusumo BHW (2008). Critical success factors influencing safety program performance in Thai construction projects. *Saf Sci,* 46:709-727.
29. Teo EAL, Ling FYY,Chong AFW (2005). Framework for project managers to manage construction safety. *Int J Proj Manag,* 23:329-341.
30. Cavazza N,Serpe A (2009). Effects of safety climate on safety norm violations: exploring the mediating role of attitudinal ambivalence toward personal protective equipment. *J Saf Res,* 40:277-283.