

Confirmatory Factor Analysis of Occupational Injuries: Presenting an Analytical Tool

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Received 2015 September 19; Revised 2016 January 06; Accepted 2016 February 01.

Abstract

Background: Occupational injuries are considered to be of great concern in all workplaces and industries, especially in the construction field.

Objectives: The purpose of this study was to determine and analyze the factors contributing to occupational injuries by means of confirmatory factor analysis (CFA).

Materials and Methods: This developmental analytical study was implemented based on occupational accidents that occurred within a five-year time frame (2009 to 2013) in 13 large Iranian construction workplaces. Modeling and data analysis were conducted by implementing the structural equations model (SEM) and CFA approaches with the use of statistical software IBM SPSS AMOS version 22.0.

Results: The results show that the individual and demographic factor (IDF), organizational factor (OF), H & S training factor (TF), workplace-human factor (WHF), factor related to type of accident occurrence (TAF), H & S risk management system factor (RMSF), and accident time factor (ATF) were considered to be effective and significant independent latent factors in occupational injuries.

Conclusions: Analytical modeling of structural equations with respect to the CFA approach has shown that occupational injuries are due to the combination of underlying indicator variables and different groups of latent factors. Hence, to determine and analyze such injuries, the role of each factor, its underlying components, and its relation with others should be considered, which will make it possible to develop a more structured approach that considers all relevant factors in order to prevent occupational injuries.

Keywords: Occupational Injuries, Factor Analysis (FA), Construction, Risk Factors

1. Background

Poor performance in workplaces, health and safety issues, and occupational injuries are each considered to be of great concern in the field of public and occupational safety and health (1-3). Generally, different factors can produce occupational injuries; some of these factors could be the nature of the workplace (which is itself sometimes dangerous), individual and organizational factors, the workplace factor, time of activities, and features of the health and safety (H & S) management structure (2, 4, 5).

Large workplaces have potential risks and an increased likelihood of accidents and human injuries. Also, the rate of occupational injuries (sometimes even fatal ones) in some fields such as construction is higher than that observed in other industries (6-9). Obviously, these damages and injuries have a negative impact on the economy, with an injury rate in construction sometimes being up to four times that of other industries (10).

Occupational injuries happen in all kinds of construc-

tion activities; therefore, the reduction of such injuries is one of the most important principles of industrial health and safety (1, 11). Moreover, the identification of causes and effective factors contributing to occupational injuries is a critical (4). For various reasons, the process involved in analyzing these injuries is very complicated. Thus, developing and applying a practical model for determining and analyzing the variables and factors contributing to the occurrence of occupational injuries requires a comprehensive understanding of such injuries (12). If the cause and effect relationship between different occupational injury factors can be defined through an analysis of different factors as well as more complicated forms of modeling, it may be possible to reduce or even prevent severe occupational injuries in construction (6).

However, even though some studies have investigated different occupational injury factors in the construction field (7, 13), it seems that the identified factors have complicated interactions with each other, and these interac-

tions cannot easily be identified, let alone thoroughly investigate them. Up to this moment, there is no available research on these interactions between different factors that may cause occupational injuries in various industries, especially in the construction field.

2. Objectives

This study has been carried out with the purpose of designing an appropriate conceptual model for determining and analyzing the important underlying indicator variables and latent factors contributing to occupational injuries, along with their relations to each other, using confirmatory factor analysis (CFA).

3. Materials and Methods

This comprehensive and analytical study was carried out with the purpose of designing an appropriate tool to determine and analyze occupational injuries by means of the structural equations model (SEM) and the confirmatory factor analysis (CFA) approach within a five-year time frame (2009-2013) in 13 large Iranian construction workplaces.

3.1. Underlying Indicator Variables

The findings of different studies have indicated that there is a collection of different variables which affect occupational injuries in the construction sector (14, 15). According to the initial blueprint for this research, the information showed that about 50 different variables have been gathered and analyzed to date. These variables include general data related to occupational accidents and injuries that have occurred in construction workplaces, such as “what,” “how,” “when,” “where,” “what type,” and “why,” which are related to H & S risk management systems in the construction projects, H & S training variables, data related to injured personnel, as well as general organizational features.

3.2. Factor Analysis

Factor analysis is a method for analyzing the variance of some dependent variables according to their description in terms of latent factors. In other words, factor analysis simplifies complicated data by describing them in terms of fewer variables. This method is used to find the underlying variables of one particular phenomenon through data reduction. Additionally, factor analysis consists of two subdivisions: exploratory and confirmatory factor analysis. If there is no relation between the different items and variables, exploratory factor analysis (EFA) is used, but if the items are identified on the basis of their relations, then confirmatory factor analysis (CFA) is used (16).

3.2.1. Exploratory Factor Analysis (EFA)

Exploratory factor analysis aims at investigating experimental data so as to discover and identify various indices and the interrelationships among them. In addition to its investigative role, it can be used in structuring, modeling, or hypothesizing because there is no definite model which is predetermined. This method of analysis is used when the researcher has no adequate documents to confirm his or her theory about the number of underlying factors, but wants to investigate the data in order to find out the number or the nature of the factors. Thus, this method is considered as a theory-producing method, not a theory-testing one (16).

3.2.2. Confirmatory Factor Analysis (CFA)

Confirmatory factor analysis is based on pre-experimental information about the structure of data which can be formed as one theory or a hypothesis, and one classified plan for variables, items based on concrete features of form and content, specific experimental conditions, or scientific knowledge of pre-studied cases. Confirmatory methods (or hypothesis tests) determine whether the data are in consonance with a specific structure of factors or not. In this analysis, it is expected that there should be a specific arrangement between variables; therefore, researchers are looking for a model in which experimental data are described and proven on the basis of fewer parameters. As a result, CFA is the best method for the construction sector (17).

3.3. Steps for Implementation

This study was carried out based on the following steps:

First Step: Accident Data Gathering:

Gathering of data on occupational injuries and their related factors was conducted through the use of literature reviews, available information in the occupational injury reports, organizational documents and records, and other related records of occupational accidents at the construction companies.

Second Step: Collecting Safety and Health Training Data:

In the second step, related data for different H & S training which was performed at the construction companies were gathered and investigated; the important factors were then extracted.

Third Step: Gathering Data on Safety and Health Risk Management Systems:

In this step, the required data on H & S risk management systems in the construction companies were gathered, and the use of systems or different methods of risk assessment were analyzed precisely. Hence, significant indi-

cator variables such as the establishment of a risk management system, hazard identification (HAZID) instruction, periodic risk assessment, the use and implementation of risk control techniques such as personal protective equipment (PPE), reporting, tool box meetings (TBM), house-keeping, and audits and inspections were extracted.

Fourth Step: Statistical Analysis:

The studied data included information on 500 occupational accidents that induced human injury which had happened within a five-year time frame in 13 large Iranian construction sites and workplaces. Thus, in this step, the underlying indicator variables and latent factors which affected accident severity were found by means of exploratory factor analysis, investigating related studies, literature review, and examination of the logical relations between underlying indicator variables. The goodness of fit of the conceptual model was then assessed using confirmatory factor analysis by means of SEM software IBM SPSS AMOS version 22.0.

Chi-square testing (χ^2) is the traditional measure for evaluating overall model fit. Root mean square error of approximation (RMSEA) is an absolute measure of fit and is based on the non-centrality parameter. RMSEA was first developed by Steiger and Lind. The comparative fit index (CFI) was first introduced by Bentler (1990) and subsequently included as part of the fit indices which take into account sample severity that performs well even when sample severity is small. The normed-fit index (NFI) analyzes the discrepancy between the chi-squared value of the hypothesized severity model and the chi-squared value of the null model. Additionally, the non-normed-fit index (NNFI), or the Tucker-Lewis index (TLI), is an incremental fit index capable of resolving some of the issues of negative bias. Values for both the NFI and NNFI range between 0 and 1 (18). Additionally, to implement this study and design an appropriate tool and model for determining and analyzing occupational injuries by means of the CFA approach, the underlying indicator variables first had to be assessed and analyzed. Then, to design an appropriate practical tool and model to analyze occupational injuries in the construction industry, factor analysis including EFA and CFA was used.

Suggested rules of thumb exist for the interpretation of the CFA indices. For acceptable fit, the ranges for the ratios χ^2/df , RMSEA, CFI, and NNFI are 2 - 3, 0.05 - 0.08, 0.95 - 1.00, and 0.95 - 1.00, respectively (18). These analyses and modeling were completed with SEM and the use of a statistical software IBM SPSS AMOS version 22.0.

4. Results

The descriptive and analytical results of the indicator variables are presented in Tables 1 to 3. According to the findings reported in Table 1, the injured workers were young and had little work experience; additionally, more than 80% of them did not have an academic education. The results also showed that about 70% of accidents were related to construction activities, while 25% were related to installation activities.

Table 1. Statistical Description of Individual and Organizational Factors

Indicator Variables	Descriptive Values
Age, y (mean ± SD)	29.18 ± 7.67
Job experience (mean ± SD)	4.67 ± 3.90
Education, No. (%)	
Sub-diploma	203 (40.6)
Diploma	209 (41.8)
Academic	88 (17.6)
Average number of workers in each activity/project (mean ± SD)	92.23 ± 77.78
Type of job, No. (%)	
Construction workers	362 (72.4)
Technicians	124 (24.8)
Drivers	14 (2.8)
Activity type, No. (%)	
Construction work	333 (66.6)
Mechanical	39 (7.8)
Installation	117 (23.4)
Electrical	11 (2.2)

The findings in Table 2 showed that the H & S training score was calculated to be at 15.4%. Moreover, indicator variables such as HAZID, risk assessment, and the implementation of risk control techniques like PPE were estimated to be at 16.4%, 16.6%, and 10.2%, respectively. The implementation of housekeeping was reported to be at 5.8%.

About half of the occupational injuries had happened in the morning and the first beginning hours of work (43%). Furthermore, the descriptive results of unsafe acts and conditions showed that they comprised 62.2% and 32.2%, respectively, of involvement in the occurrence of accidents (Table 3).

The results of factor analysis including EFA and CFA for designing a practical tool to analyze occupational injuries in the construction industry, and the findings of the goodness of fit indices of the conceptual model, are presented in Table 4. The values of indices such as χ^2/df , RMSEA, CFI,

Table 2. Descriptive Results of Indicator Variables Related to H & S Training and Risk Management

Indicator Variables	Descriptive Values, No. (%)
Pre-employment training	240 (48.0)
Periodic training	110 (22.0)
Past accident training	88 (17.6)
PPE training	105 (21.0)
Housekeeping training	16 (3.2)
Duration of training	132 (26.4)
Content of training	71 (14.2)
Training score	77 (15.4)
Risk management system	92 (18.4)
HAZID	82 (16.4)
Periodic risk assessment	84 (16.6)
Control measures	51 (10.2)
Housekeeping	29 (5.8)
Toolbox meeting	53 (10.6)
Reporting	48 (9.6)
Audit and inspection	41 (8.2)

and NNFI were 3.083, 0.065, 0.960, and 0.972, respectively. Therefore, this model is acceptable according to the results of the goodness of fit analysis.

Additionally, the findings related to the design of a preferred model of effective factors of occupational injuries and the considered names of each latent factor are given in Table 5. According to the results, there is a significant impact of the latent factors on the underlying indicator variables ($P < 0.01$). Moreover, the findings of the designed model based on the CFA showed that 39 underlying indicator variables, which are presented in Tables 1 to 3, significantly affected seven independent latent factors: the individual and demographic factor (IDF), the organizational factor (OF), the H & S training factor (TF), the workplace-human factor (WHF), the factor related to types of accident occurrence (TAF), the H & S risk management system factor (RMSF), and finally, the accident time factor (ATF).

5. Discussion

The findings of this developmental and analytical research project indicated that occupational injuries are the outcome of different variables and factors that occur at different levels, such as with management and superintending, and in the individual's occupational working environment. Conclusively, injuries in construction happen as a result of a fault or failure in the interactions between

Table 3. Findings of Indicator Variables Related to Construction Injuries

Indicator variables	Descriptive Values, No. (%)
Machinery	59 (11.8)
Equipment	105 (21.0)
Electricity	45 (9.0)
Hand tools	39 (7.8)
Chemical	36 (7.2)
Unsafe conditions	161 (32.2)
Unsafe acts	311 (62.2)
Fall	113 (22.6)
Throwing objects	113 (22.6)
Slipping	108 (21.6)
Collision	86 (17.2)
Electrical shock	48 (9.6)
Chemical splurge	36 (7.2)
MMH	74 (14.8)
Year	
2009	157 (31.4)
2010	150 (30.0)
2011	79 (15.8)
2012	62 (12.4)
2013	52 (10.4)
Season	
Spring	119 (23.8)
Summer	199 (39.8)
Autumn	121 (24.2)
Winter	61 (12.2)
Time of day	
Morning (8 - 11)	215 (43.0)
Midday (12 - 15)	129 (25.8)
Late afternoon (16 - 18)	156 (31.2)

Table 4. Model fit indices in the Model Building Process for Occupational Injuries

Indices	Value
χ^2	2389.879
χ^2/df	3.083
RMSEA	0.065
CFI	0.960
NNFI (TLI)	0.972

workers, the workplace, the materials, and the equipment

Table 5. Regression Weights of the Path Model

Path	Estimate	S.E.	C.R.	P
Idf on education	1.0	-	-	-
Idf on age	4.51	0.261	20.846	0.001
Idf on experience	10.61	0.516	20.584	0.001
Of on number of workers	1.0	-	-	-
Of on job	0.054	0.001	7.706	0.001
Of on activity	0.067	0.001	14.836	0.001
Tf on pre-employment	1.0	-	-	-
Tf on periodic	0.997	0.017	60.390	0.001
Tf on past-accident	1.015	0.016	63.726	0.001
Tf on ppe	0.632	0.025	25.491	0.001
Tf on housekeeping	0.430	0.032	13.433	0.001
Tf on duration	0.358	0.022	15.909	0.001
Tf on content	0.589	0.025	23.232	0.001
Tf on final score	0.505	0.024	21.463	0.001
Whif on electricity	1.0	-	-	-
Whif on equipment	3.173	1.218	2.605	0.009
Whif on machinery	2.898	1.116	2.598	0.009
Whif on hand-tools	2.405	0.914	2.630	0.009
Whif on chemical	1.714	0.679	2.524	0.012
Whif on unsafe condition	1.726	0.366	4.713	0.001
Whif on unsafe act	3.110	1.213	2.563	0.010
Taf on fall	1.0	-	-	-
Taf on throwing objects	0.258	0.044	5.834	0.001
Taf on slipping	0.108	0.044	2.457	0.014
Taf on collision	0.185	0.038	4.929	0.001
Taf on electrical shock	0.065	0.038	1.727	0.048
Taf on chemical	0.683	0.338	2.024	0.043
Taf on mmh	0.564	0.017	34.081	
Rmsf on hazid	1.0	-	-	-
Rmsf on ppe	0.234	0.016	14.864	0.001
Rmsf on risk assessment	0.324	0.019	16.702	0.001
Rmsf on rms	0.725	0.028	25.695	0.001
Rmsf on housekeeping	0.057	0.023	2.460	0.014
Rmsf on audit	0.076	0.010	7.989	0.001
Rmsf on tbm	0.418	0.023	18.552	0.001
Rmsf on reporting	0.433	0.022	20.036	0.001
Atf on year	1.0	-	-	-
Atf on season	3.078	1.204	2.555	0.011
Atf on time of day	4.035	1.541	2.618	0.009

used by workers. Therefore, to perform a practical accident causal analysis, it is recommended that more systematic steps be followed. Different studies that have investigated underlying reasons or a collection of factors related to this content were considered in this study (7, 12).

This study was done with the purpose of designing an appropriate tool to determine and systematically analyze the effective variables and factors contributing to occupational injuries in the construction industry. Therefore, exploratory and confirmatory factor analyses of 50 different indicator variables, which were carried out in the form of SEM, indicated that 39 out of 50 variables were identified to be underlying indicator variables for human injury arising from occupational accidents in the construction industry, and these variables should be given more attention.

The conceptual model of the 39 underlying indicator variables was developed based on investigating the available literature, as well as by using exploratory factor analysis on seven independent latent factors, which included the individual and demographical factors (IDF) (19), the organizational factor (OF) (20), the H & S training factor (TF) (21-23), the workplace-human factor (WHF) (12, 14, 20), the type of accident occurrence factor (TAF) (14, 24), the H & S risk management system factor (RMSF) (15, 20, 23), and the accident time factor (ATF) (20, 25). Analysis of the conceptual model using confirmatory factor analysis indicated that the impact of each of the seven latent factors on the underlying indicator variables was significant, and additionally, the fit of this model was acceptable. Furthermore, all of these findings revealed that the designed tool could be a practical and preferred model for analyzing the effective factors of occupational injuries, especially in construction (9, 15, 26-29).

5.1. Individual and Demographic Factor (IDF)

The results of the factor analysis in this study revealed that indicator variables such as average age, work experience, and education were considered as part of the latent individual and demographic factor. In addition to being a direct part of IDF, they also play an important role as mediating factors in occupational accidents. For instance, Salminen showed that "age" as an individual indicator variable plays a significant role in occupational accidents (19).

5.2. Organizational Factor (OF)

In this study, job title, activity type, and the number of workers involved in construction activities or projects which led to accidents were mentioned as part of the latent organizational and management-related structure factor. The latent organizational factor is one of the most important factors affecting occupational injuries. Consequently,

this factor and its indicator variables can themselves cause problems in the process of safe implementation or may be influenced by other underlying factors, thereby affecting occupational injuries indirectly (20).

5.3. Workplace-Human Factor (WHF)

Based on the developed conceptual model, the findings related to failure in machinery, equipment, hand tools, electrical devices, chemicals, material handling, and unsafe acts and conditions were identified as components of the human workplace factor. This latent factor can also interact with other factors, especially individual and organizational ones, and thus worsen occupational injuries (12, 14, 20).

Clearly, human error is one of the basic causes of occupational injuries. Unsafe acts are considered to be one of the most important causes directly leading to occupational injuries (20, 27). It has also been shown by Haslam and colleagues that one worker or a group of workers play a direct role in 70% of construction injuries which occur because of human error or unsafe acts. Additionally, unsafe behaviors could be influenced by other important factors like the demographic and organizational factors, working environment conditions and the workplace-human factor, accident time and its geographical location, as well as types of construction activities (14, 20, 24).

5.4. Type of Accident Occurrence Factor (TAF)

Indicator variables including falling, throwing objects, slipping, crashes and collisions, chemical spilling, contact with objects or electrical circuits, and injuries arising from manual handling were specified as part of the latent accident type factor (TAF), which is the last factor before an accident happens. This factor is more important because its related indicator variables have a direct role in occupational injuries. Therefore, this latent factor can be used to better identify and analyze occupational injuries in the construction industry (14, 24).

5.5. Safety and Health Training Factor (TF)

Underlying indicator variables include pre-employment H & S training, periodic training, training after injury occurrence, PPE training, housekeeping training, duration and content of training courses, and the final score of H&S training comprised the latent H & S training factor (TF). Research has shown that inappropriate and inadequate training can lead to carelessness, dangerous behaviors, and different kinds of human errors which can affect the rate of occupational injuries (21-23). A large number of studies revealed that hazard identification and risk perception can be improved through H&S training

(22, 23). Therefore, consideration of H& S training and the promotion of training indicators may be useful in hazard and risk identification. Consequently, such insight will promote safety and health in various industries and reduce the number and severity of accidents (22, 23). Workers' awareness of PPE and housekeeping procedures are some of the more significant H&S training indicator variables in the construction industry (20).

5.6. Safety and Health Risk Management System Factor (RMSF)

The construction industry is faced with a high H & S risk working environment, which sometimes can be catastrophic (15); therefore, the establishment and enforcement of H & S management systems and the consideration of their underlying indicator variables can improve the process of systematic hazard and risk identification, and also reduce the number of occupational injuries (23). The latent risk management factor in this study was comprised of indicator variables such as the establishment of risk management system, the performance of regular and codified activities which are related to hazard identification (HAZID), periodic risk assessment, the implementation of appropriate control measures such as PPE, the implementation of a proper housekeeping system, the settlement of H & S tool box meetings at the beginning and the end of work shifts (TBM), the implementation of report system for incidents, including "near miss" or even insignificant accidents which involved workers, and finally, the establishment of an H & S audit and inspection process. Sequentially, some studies have indicated that poor performance of H & S management systems and failure in implementation of risk management systems, such as failures in hazard identification, inadequate H & S risk assessment, inappropriate risk assessment methods, insufficient control measures including housekeeping, or even lack of control devices such as PPE, are the most effective indicator variables and causes of occupational injuries in the construction industry (20).

5.7. Accident Time Factor (ATF)

The accident time factor was introduced by indicator variables such as year and season in which injuries had happened as well as the exact time of occurrence during the work day. Accident time is a significant factor in occupational injury analysis. Some of the studies showed that a large number of injuries usually happen at the beginning of shift work and also near the end of a shift due to exhaustion from long hours of tedious work. Moreover, accident time can be influenced by climate conditions and the geographical location of the construction site (20, 25).

Finally, the findings of this developmental and analytical study have shown that the studied indicator variables

in the form of the seven latent factors are valid and can be used to develop an appropriate model for analyzing occupational injuries.

5.8. Conclusion

Occupational injuries in construction are due to failures in a variety of factors and different variables, and the interaction of these causal factors and variables. According to the complexity of the occurrence and the nature and severity of construction injuries, designing a tool and a model for occupational injury analysis that can account for all of the related factors can be useful. It is also important to note that due to the established validity of this conceptual tool using confirmatory factor analysis, may be used to analyze occupational injuries.

Acknowledgments

The authors wish to sincerely thank the health and safety engineers for their invaluable and skillful assistance in data gathering.

Footnotes

Authors' Contribution: The idea of the study was developed by Iraj Mohammadfam and Ahmad Soltanzadeh; Ahmad Soltanzadeh undertook the literature search and collected the data; Ahmad Soltanzadeh, Abbas Moghimbeigi, and Mahdi Akbarzadeh analyzed the data and synthesized the results; Ahmad Soltanzadeh and Iraj Mohammadfam drafted the manuscript; Abbas Moghimbeigi and Mahdi Akbarzadeh contributed to thematic analysis and reviewed the draft of the manuscript; All authors contributed significantly to revisions and approved of the final manuscript.

Conflicts of Interest: The authors declare that they have no competing interests. Any opinions stated are those of the authors and not of their parent institutions.

Funding/Support: This study was supported by the research center for health sciences of the Hamadan University of Medical Sciences, Iran.

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