

Research Article

An Empirical Research of Correlation Analysis on Engineering Construction Safety Influencing Factors

¹Yunsheng Zhao and ^{1,2}Sixin Song

¹College of Engineering, China University of Geosciences, Wuhan, 430074, China

²China Three Gorges Project Corporation, Beijing, 100038, China

Abstract: The correlation analysis of the independence between the behavioral influencing factors has been performed in order to find the non-independent factors. Among the Human Factors Analysis and Classification System (HFACS), the impact of the high-level factors on the bottom level is determined. This study uses empirical method, namely Structural Equation Modeling (SEM) to build the relationship model. After finishing the framework of construction safety influencing factors, we design the questionnaire survey, ultimately draw SEM model by AMOS software. The results by AMOS show that the model can effectively describe the relationship between the influence factors of which affecting construction safety and provide strong evidence for improving the engineering and construction management.

Keywords: Construction safety influencing factors, correlation analysis, empirical research

INTRODUCTION

At present, China's engineering construction safety management system is gradually standardized, the safety management also achieves a more significant result, but the overall situation remains grim. Engineering construction management is a very important link in the whole project, for large and medium-sized construction process, there is still many problems and contradictions about construction management. In order to create a good environment for production safety and improve the safety of the construction index, we must find out the insecurity factors in the construction process, including management factors and the actual situation. And then improve the unsafe conditions, to minimize or avoid the occurrence of accidents, ensure the safety of personnel and property.

However, there are only a few studies on the engineering construction safety influencing factors at present. Lu Bingwu put forward five key factors of the quality control of hydraulic engineering construction (Lu, 2012); P.S. Paul, J. Maiti have studied the behavior factors which the underground mine safety management involves (Paul and Maiti, 2007); Dedobbeleer and Beland have determined the construction work system's safety security performance standards, then associate the security atmosphere with work place's actual characteristic which achieve by the questionnaire (Dedobbeleer and Beland, 1991); Metin D., Ihsan Y.,

Mustafa K pointed out in their research prospect, could analyze the accident statistics by statistical methods, thereby determine the dependencies between the various risk factors more accurately (Metin *et al.*, 2008); Colin R also pointed out that this is the focus of future research (Colin and Peter, 2009).

In domestic, the majority stresses on theoretical research, very few carries on the analysis through the actual data modeling, meanwhile some overseas research, limited to a particular field, on the selection of the factors not formed a theoretical system which from the management to field work personnel's and top-down, also failed to determine the relationship of interdependence between the factors accurately. This study intends to use structural equation modeling to build a four-layer model to analyze the factors affecting engineering construction safety, of which factors involve to upper management and field construction workers, aims to analysis sources of risk in project construction process from the global.

Structure Equation Modeling (SEM) is a statistical method applying linear equation system expressed the relationship between observed variables and latent variables, which can be used to estimate the parameters of the quantitative cannot be directly quantization. Yet the application of Structural Equation Modeling (SEM) in domestic is relatively late, In the research papers published in the 1960s, appeared to see the application of SEM. Zhang Xian, Wang Xueqing used structural equation model to carry on modeling the causal

relationship between the construction project system complexity measure indexes (Zhang and Wang, 2011); Chen Lianhua, Li Shuguang established the eight-level indicators of structural equation model for coal mine accident emergency response capacity, used the questionnaire obtained data, results showed that the evaluation system was reasonable (Chen *et al.*, 2011); H.A. Bassioni and T.M. Hassan studied on the quality management model of construction contractors by SEM, showed that work atmosphere, cooperative relations, risk management and process control have positive impact on performance (Bassioni *et al.*, 2007).

The research object of this study is a series of variables cannot be directly observed which involve the engineering construction safety influencing factors. It is too difficult to use traditional statistical methods such as correlation analysis and regression analysis methods to draw the result of the interaction of all factors. Therefore, use Structural Equation Modeling (SEM) to analyze the relationship between the construction safety influencing factors. Moreover domestic uses SEM to carry on this aspect of empirical study basically to be at the blank stage.

FACTOR ANALYSIS AND THE QUESTIONNAIRE

Factor analysis: We preliminary draw construction safety influencing factors through analyzing the Three Gorges group's "Key Dangerous Source Process monitoring Program file", the Three Gorges Project's accident case statistics in 2005 and 2006, the production safety accident cases statistics of Xiluodu project from 2005 to 2011, the accident case statistics of Xiangjiaba dam project in 2005 to 2009 year, combined with other references and the national formulation each kind of construction standard of security standard. We made pre investigation on the safety and technical director of the department, security management, construction management, supervision engineers, professional engineers, field workers and other construction and engineering personnel of the security-related, determines four broad heading and 19 kind of factors index finally. Four broad headings are respective enterprise influence, security management, field work related factors and construction personnel safety related factors. And the enterprise affects layer including safety production objective, organization and responsibility, safety production investment, laws and regulations and safety management system; security

management including education training, safety supervision and inspection and acceptance, risk monitoring, emergency rescue, accident report and investigation processing; the field operation related factors including job environment, technical measure, teams and groups management, personnel basic situation, occupational health, mechanical device and material; the construction personnel safety related factors including perception and decision-making capacity, job skills and operating irregularities.

Questionnaire implementation: The raw data of this study using the questionnaire to obtain. Questionnaire method is a kind of traditional evaluation method for teaching work. People in normal condition are tested by questionnaire, test or scale, then obtain data evaluation and make judgments. In this study, we finally got questionnaire with 68 detailed targets after variable discusses and repeatedly revises. And the enterprise influence layer including 10 topics, the security control layer including 25 topics, the field operation correlation factors layer including 26 topics, the construction personnel safety related factors layer including 7 topics.

To get the comprehensive information, we had issued questionnaires in all kinds of workers for water conservancy construction including safety or technical director of the department, safety manager, construction manager, supervision engineer, technical engineer, field work personnel and other engineering construction safety related personnel.

This survey altogether provides 418 piece of questionnaire. Questionnaire samples arrangement job: in a piece of questionnaire, if there are a number of answers missing, the record is deleted, if the answer choice is too single, also delete the record. Finally, obtains 289 piece of valid record and based on this making analysis.

The reliability and validity of the inspection: This research uses the SPSS 17.0 study the internal consistency of the data. In SPSS 17.0, Alpha model is used to carries on the reliability analysis for four broad heading targets; we finally get the analysis result as the following table. Table 1 shows the test result of latent variables' reliability and validity.

Table 2 shows the reliability analysis results of all data. Table 3 gives the KMO and Bartlett's test results. By the result of SPSS software we may see, the alpha coefficient for each subscale is well; over than 0.5 and the total scale of the Cronbach's Alpha

Table 1: The test result of latent variables' reliability and validity

Latent variable	Number of measurable variable	KMO	Bartlett's test			
			Approx. chi-square	Df	Sig.	Cronbach's alpha (α value)
Enterprise influence	4	0.675	177.907	6	0.000	0.510
Safety management	5	0.854	536.007	10	0.000	0.822
Field work	7	0.918	1074.889	21	0.000	0.883
Construction workers'	3	0.727	342.280	3	0.000	0.816

Table 2: The reliability analysis results of all data

Cronbach's alpha (α value)	Number of items
0.916	19

Table 3: The KMO and Bartlett's test results

KMO and Bartlett's test	
Kaiser-Meyer-Olkin measure of sampling adequacy	0.923
Bartlett's test of Sphericity	Approx. chi-square 2924.223
	Df 171
	Sig. 0.000

coefficient is 0.916, very close to 1 which means the high reliability of this scale data. Simultaneously the KMO Bartlett and check values of each subscale is preferable and the total scale's KMO value is 0.923, very close to 1, Sig.<0.05, indicating that this questionnaire's structural validity is very good. In summary, the reliability and validity of the questionnaire is quite desirable.

THE ANALYSIS BASED ON EMPIRICAL SEM

Model comparisons: In this study, we use the AMOS 18.0 for model modeling. According to causal relation between the hidden variables, the basic element of structural equation model has been determined. In addition to the four main latent variables and 19 observed variables in the model, also introduces a number of residual variables. Nineteen observed variables has 19 residual variable e1, e2, e3... .. e19, 3 hidden variables has three residual variable z1, z2 and z3. Because of the indexes obtained from questionnaire will inevitably has error, in order to make the model can be verified path and concept model demonstrated, the introduction of residual variable is indispensable.

In order to obtain the mutual influence relationship among the factors to be calculated the path coefficients between variables, the residual variables associated with the path coefficient is set to 1, set one of the Path Parameters to 1 which belongs to the latent variables point to the observable variables. Then questionnaire data which had validated through SPSS software will be imported into the model as input to structural equation modeling. We may get correlation coefficient for every path by AMOS 18.0. Finally, we get basic structural equation model.

When parameter setting is completed, run the software to analyze the model fitting. Obtains this model's commonly used fitting index computed result as shown in Table 4.

Design the model by software in the same way and then import the survey data to calculate the path coefficients for each variable. Obtain the basic structural equation model and the commonly used fit index calculation results are shown in Table 5.

About fitting index, chi-square value is the smaller, the better; CFI, NFI, IFI, RFI and GFI is to belong to

Table 4: Commonly used fitting index computed result of first model

Fit index	Chi-square				
	value	DOF	CFI	NFI	IFI
Result	409.305	149	0.908	0.864	0.909
RFI	RMSEA	AIC	BCC	GFI	RMR
0.843	0.078	491.305	497.424	0.872	0.160

Table 5: Commonly used fitting index computed result of second model

Fit index	Chi-square				
	value	DOF	CFI	NFI	IFI
Result	565.800	167	0.862	0.816	0.863
RFI	RMSEA	AIC	BCC	GFI	RMR
0.791	0.091	651.778	658.542	0.831	0.200

between 0 and 1, the more close to one means the better fitting degree model; RMSEA less than or equal to 0.05, model fitting is good, if RMSEA less than 0.08, the appropriate model fitting; AIC and BCC are value smaller may be more beautiful; RMR is residual RMS, the value is smaller, the model fitting is better.

According to the results show by the output of AMOS software, the two model design can be accepted, but contrast Table 4 and 5, the result of model fitting index indicate that the first model's fitting parameters are more satisfying, simultaneously the first model also conforms to the practical significance of this research. Therefore, chooses the first model to carry on the revision and result analysis.

Model revision: The model revision mainly has two main cases: one is changing the original set of the model by increase or decrease the hidden variable or the obviously variable, another is to change the condition of the parameters to be estimated, means making the fixed parameters as free parameters and then reexamine the model checking's value to reduce it at least.

Amos offers two kind of model modification index, of which fixed Index (Modification Index) used to model expands, the Critical Ratio (Critical Ratio) used to model restriction.

Observe the M.I. value in the AMOS's output. The M.I. value is the revised index, which can discover meaningful information for improving the model's fitting situation. Before the correction, you must check whether the path is correct in the model, that variable is really relevant, only significant regression coefficients is not equal to 0 representing the path relationship between variables is correct. When model updating, the higher modification index the path to choose with, more conducive to improving the model's fitting situation.

After repeated estimation model and constantly check the AMOS's output, looking for variable with high M.I. value, closely linked to the practical significance of the model to increase the correlation path, simultaneously contact with the practical

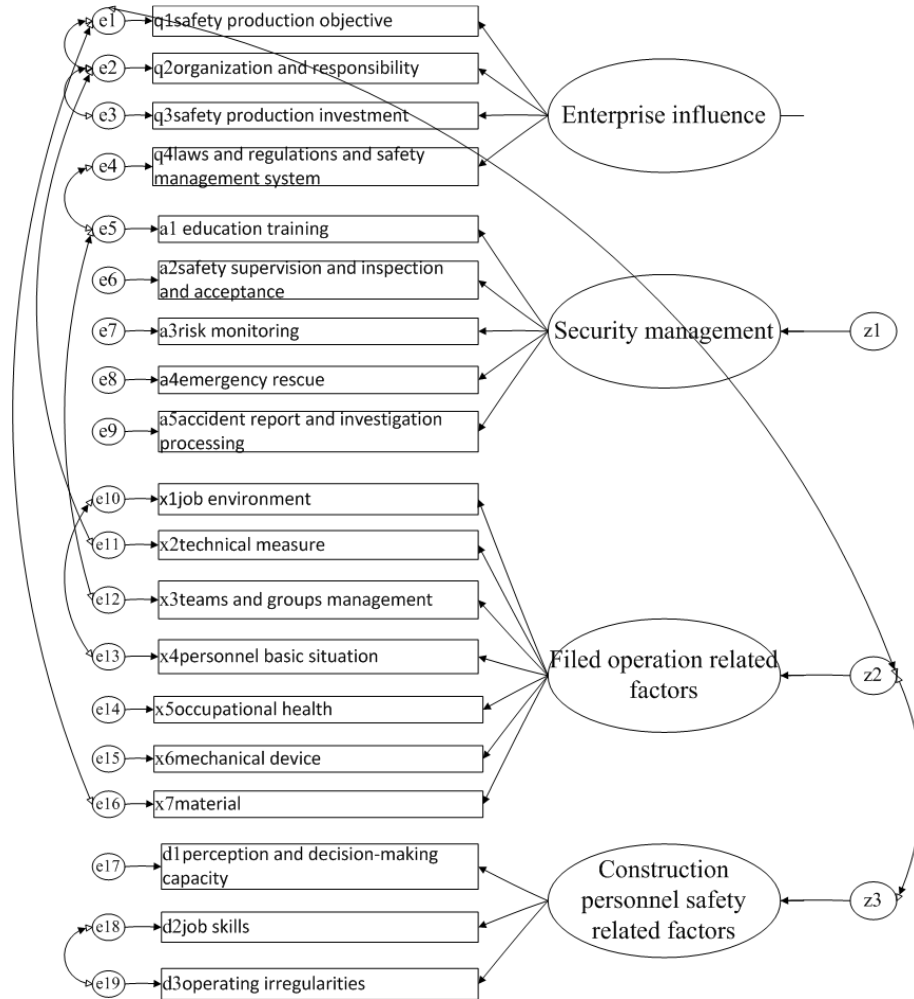


Fig. 1: Correlation analysis of factors of SEM model in HFACS framework

Table 6: Commonly used fitting index computed result of revised model

Fit index	Chi-square value	DOF	CFI	NFI	IFI
Result	238.487	139	0.965	0.920	0.965
RFI	RMSEA	AIC	BCC	GFI	RMR
0.902	0.050	340.487	348.099	0.924	0.127

significance of the model to increase the correlation path. Eventually, we get the fixed model as shown in Fig. 1 and model fitting index as shown in Table 6.

Make comparison from Table 4 to 6, we can see that the corrected model's chi-square value decrease and fit indices have been greatly improved, revised model's fitting situation get even better.

Model explanation: By the correlation coefficient between the variables of the model >0 can be seen, the relationship between each latent variable are positively correlated, indicating that one of the latent variable will have a positive impact on another latent variable. Similarly, the impact between the latent variable and its corresponding observable variables is positive.

- We may know by the AMOS analysis result, in the enterprise influence layer, the laws and regulations and the safety control system's standardization path coefficient is the highest, achieves 0.827, which indicate in this level laws and regulations and the safety control system's formulation has the very big influence, the enterprise must establish and improve all kind of safety control rules and regulations and promptly gain and recognition country's laws and regulations about safety in production. The implement of laws, regulations and the safety control system will enhance the corporate influence; will enable the enterprise to start from the management, so that the enterprise from the management began to minimize the number of construction accident.
- In security management layer, emergency rescue's standardization path coefficient is the highest, the value is 0.765, followed by risk monitoring, value of 0.748, again is education and training, at 0.735, obviously emergency rescue in this layer is the biggest influence. Enterprises should establish safety and emergency management agencies with

adapted emergency rescue teams, improve emergency response facilities and equipment, when accident occurs, must start the related emergency plans, carry out the emergency recovery positively. At the same time risk monitoring and education training's standardization path coefficient is very high, should also pay attention to these two aspects. Before the accident occurs, preventing is the first work; the enterprise must strengthen the safety education and training, strengthen staff's safety consciousness and safety protection ability. To dangerous places or facilities, it is necessary to conduct hazard identification, assessment and registration promptly, if only determined for hazardous source, must take the measure to carry on the monitoring.

- Field work related factors include the field work environment, technical measures, team management, personnel basic situation, occupational health, mechanical equipment and others, are mainly the objective factors. Based on the analysis of model results, in this layer, occupational health's standardized path coefficient is 0.813, show the biggest influence in this layer; followed by team management, coefficient value of 0.810, at this level should pay attention to occupational health and the role of team management. On the one hand, enterprise should provide employees with health work environment which conform to the occupational requirement, carries on the examination regularly to the operational site, gives the immediate cure to occupational disease patient according to the stipulation and consummates the occupational hazards warning work. On the other hand, before entering construction site, be sure to carry out "predict dangerous activity", emphasis on teamwork between the team members, moderate pace of construction and schedule to be reasonable.
- There are three targets in construction workers' security correlation factor layer, they are the perception and decision-making capabilities, job skills and operating irregularities, according to the AMOS output result and the standardization path coefficient respectively is 0.901, 0.684 and 0.709. Therefore, perception and decision-making capabilities influence this level's most, followed by job skills and operational violations. Showing in constructors' unsafe behaviors which lead to accidents, not familiar with external conditions, the environment factors and construction equipment status lead to more times mistake; inexperience, lack of training or external pressure, the understanding question not thorough and so on create the policy-making mistake also in causes in the process which the accident occurs the influential role; attention not centralized,

assignment not, when with could not control the attention simultaneously to increase the possibility which the accident occurred. Therefore, in construction process should be noted that to overcome these errors.

- **The interaction between hidden variables:** The correlation coefficient between enterprise influence and the safety management, the correlation coefficient between safety management and field work related factors, the correlation coefficient between field works related factors and construction workers' security correlation factor are respectively 0.839, 0.791 and 0.576. Therefore the safety management affected by enterprise influence layers most, strengthen the enterprise influence and improve laws, regulations and safety management system is the most important job for engineering construction safety. Safety management and field work related factors of two latent variables' correlation coefficient was 0.791, which means enhance the influence of safety management, field operations related factors can be improved. The correlation coefficient between fields works related factors and construction workers' security correlation factor is only 0.576, the third tier factors on the fourth level factors influence the intensity minimum. Explains the third layer's factors relatively independence to the fourth layer.

CONCLUSION

This study bases on structural equation model SEM, carries on the top-down analysis to the project construction's safe influencing factor, altogether determines 19 key indicators, then uses Likert scale method to design questionnaire, gains the primary data through the questionnaire survey, after that uses software AMOS to carry on the comparison, the evaluation and revision to structural equation model, finally, concludes the relationship between the construction safety influencing factors. This study provides a certain reference value for management of the construction of the project on laying down the regulations and taking measures. Limited by the content of this study, there remains to be further analysis for more accurate and detailed risk factors and construct a more reasonable empirical model.

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