

The Establishment of Cause-System of Poor Construction Site Safety and Priority Analysis from Different Perspectives

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Abstract—Construction site safety in China has aroused comprehensive concern all over the world. It is imperative to investigate the main causes of poor construction site safety. This paper divides all the causes into four aspects, namely the factors of workers, object, environment and management and sets up the accident causes element system based on Delphi Method. This is followed by the application of structural equation modeling to examine the importance of each aspect of causes from the standpoints of different roles related to the construction respectively. The results indicate that all the four aspects of factors are in need of improvement, and different roles have different ideas considering the priority of those factors. The paper has instructive significance for the practitioners to take measures to improve construction site safety in China accordingly.

Keywords—construction site safety, Delphi Method, structural equation modeling, different perspective.

I. INTRODUCTION

CONSTRUCTION is one of the most accident-prone industries due to its unique nature [1]. Minor accidents may obstruct production, and a serious accident can produce a variety of problems, having its implications for delivery, schedule, quality, cost, and even social responsibility. China, as a representative of developing countries, has gained a poor reputation for high accidents rate on construction site. According to the statistics reported by the Ministry of Housing and Urban-Rural Development of P.R. China, 590 accidents happened and 734 workers were killed in 2010, with a remarkable increase respectively compared to the year before [2]. However, the situation is still serious. The combination of the social responsibility and economic pressures has triggered the need for the reduction of workplace accidents and improvement of construction site safety [3]. Thus the first step is to find out the critical causes of the problem of poor construction site safety.

There is a body of empirical studies exploring a wide variety of factors affecting the safety on construction site in China, utilizing a mixture of different types of methodology. Reference [4] identified elements of poor construction safety management in China which included poor safety awareness of top management, lack of training, poor safety awareness of project managers, reluctance to input resources to safety and

reckless operations. Reference [5] integrated 7 comprehensive factors which were human, equipment and material, survey and design, the project decision making safety, qualification grade, security cost and new technologies through factor analysis. Reference [6] set up the appraisal system for construction site safety, and considered labor subcontract factors.

However, reviews of the existing literature have highlighted the empirical evidence as being contradictory and confusing. The reason may be that they have lacked a coherent taxonomy, leading to a wide variety of factors being measured. Reference [7] set up the comprehensive safety management appraisal system for construction enterprises based on information entropy, in which he divided the factors into four aspects, namely the factor of human, construction equipment, environment and management, which has instructive significance to this paper. In this paper all the factors are re-sort out into 4 aspects which are worker, object, environment and management.

Besides, there are many kinds of roles related to construction safety, thus, it is significant to investigate them independently in order to find out these differences and make improvement accordingly.

Although many researchers have investigated the critical contributors to the poor construction safety situation of China, none of them have made a clear category with appropriate methods from different perspective. This paper contributes to establishing the system of causes of poor safety on construction site based on Delphi Method and empirical analyzing of the priority of those causes utilizing structural equation modeling (SEM) from different perspective (managers, workers and the clients), considering that those three kinds of roles may harbour different reservations.

II. ESTABLISHMENT OF THE CAUSE SYSTEM

To establish the system of causes of poor safety on construction site, we have invited 9 personnel, including 3 general site staff, 3 managerial staff and 3 scholars, to come up with the ideas with Delphi Method. All the general site staff and managerial staff have more than 6 years of working experience in the construction industry, and the 3 scholars are famous for their studies on construction safety. They are chosen because they have the necessary knowledge and working experience in handling construction projects.

Based on literature review and the result of Delphi Method, the researchers have developed the factor-system which comprises 4 first-class indicators and 28 corresponding sub-indicators. The details are listed in figure 1.

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The factors of worker

Unsafe behaviors of workers are said to both directly and indirectly contribute to nearly 90% of all workplace accidents and incidents and there is no exception on construction site in China. It is estimated that 80% of the construction site workers are originally peasants who move to the urban regions from countryside to make a living. Those peasant laborers have low educational level, less safety awareness, insufficient safety knowledge, awkward skill, much work pressure, low job satisfaction, and more than 95% of accidents can be attached to them. Thus worker factors play a vital role on construction site in China.

The worker factor includes 7 corresponding sub-indicators which are low educational level, less safety awareness, insufficient safety knowledge, awkward skill, work overtime, bad habits and unsafe behavioral.

The factors of object

Object factor consider the production equipment, personal protection equipment and construction material comprehensively.

Reference [8] emphasized that today's construction projects are highly mechanized and the use of production equipment has become commonplace within Chinese construction industry. Personal protection equipment (PPE) has also gained much attention on construction site as it is the most direct and important measure to protect individuals from injury if accident happens. In terms of construction material, its quality is the key point of construction quality, and influences the safety of the whole construction process.

The object factor constitutes of 6 corresponding indicators, namely lack of safety note boards and slogans, low quality of production equipment, lack of maintenance of production equipment, lack of allocation of personal protection equipment, lack of maintenance of personal protection equipment and low quality of construction material.

The factors of environment

Environment here covers both natural environment and working environment. Because the construction site is exposed to geological and weather conditions, which may affect the construction safety, it is necessary to consider natural environment. Meanwhile, many potential safety hazards stem from working during the construction process, such as the noise, the dust, the obstacle, the temporary electricity, the high level working, etc.

The environment factor consists of 7 corresponding indicators: hidden trouble of geologic hazard, hidden trouble of bad weather, dim light and much noise, hidden trouble of fire, hidden trouble of electricity, hidden trouble of high-level working, and hidden trouble of blasting.

The factors of management

The aim of safety management is to ensure that the human and object are at safe conditions and to tackle environmental problems. And it is always associated with safety management rules and regulations. It is widely believed that safety management plays the dominant role in construction safety.

Management factor constitutes of 8 corresponding

indicators: lack of safety training, lack of safety investment, lack of regular safety meetings, lack of emergency preparedness, lack of safety management regulations, lack of enforcement of safety regulations, lack of incident investigation and analysis, lack of management of sub-contractors.

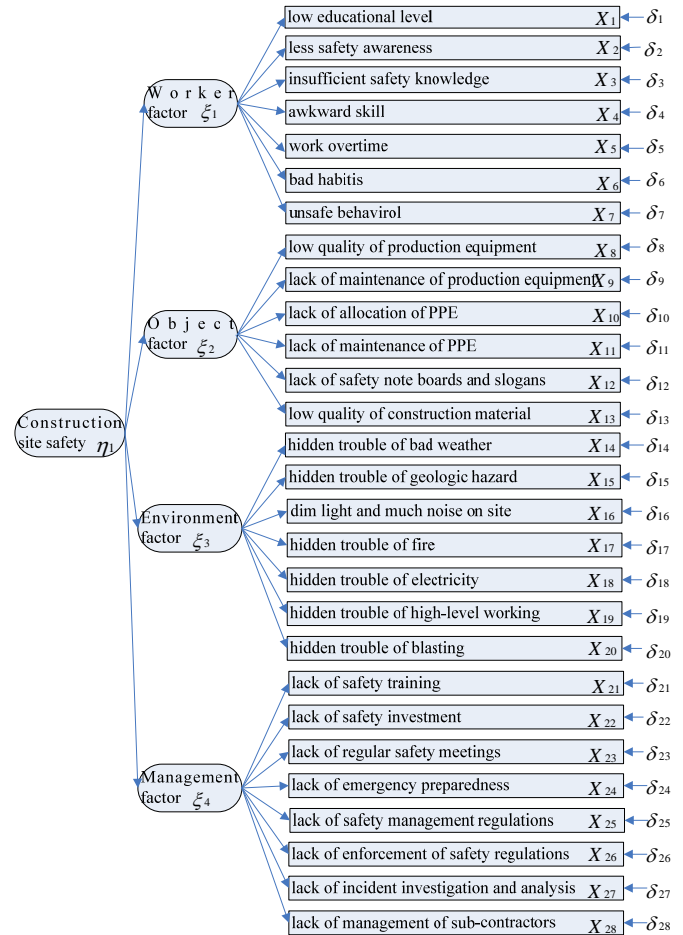


Fig. 1 Conceptual model of causes of poor construction site safety

III. METHODS

Data collection

A questionnaire showing all the observed exogenous variables (X) was designed. Respondents were asked to rate the extent to which each variable affecting the construction site safety on a 5-point scale where 1=not important, 2=less important 3=neutral, 4=important and 5=very important (critical). The participants in this study were classified within three groups, namely the Managers Group (MG), the Workers Group (WG) and the Clients Group (CG). The MG consisted of the managers from contractor, owner and supervision. The WG were the workers on construction site. The CG included the scholars who are focused on the construction site safety and auditors from the government. 300 questionnaires were distributed to all the three groups evenly with an overall response rate of 79%. The questionnaires were distributed respectively, so it is supposed that the participants filled them independently.

Structural equation modeling

The factors affecting the construction site safety are excessive, subjective and difficult to observe directly, and in addition, the error margin of measurement is great. Therefore, adopting multiple linear regression or factor analysis to analyze the data is undesirable. The Linear Structural Relations computer program developed by Joreskog and Sorbom was used to estimate the structural relations [9]. According to [10], it was advisable to adopt SEM to handle data in construction in order to overcome the shortcomings of quantitative analysis. And SEM has many unique advantages compared to most other linear parameter statistical methods, including treatment of both endogenous and exogenous variables as random variables with errors of measurement, latent variables with multiple indicators, test of a model overall rather than coefficients individually, accounting for missing data, and handling of non-normal data [11]. Thus the paper adopts SEM to measure the relationships between construction site safety and contributory factors from different perspectives.

The SEM model can be disintegrated into two sub-models: a measurement model and a structural model. The measurement model defines relationships between observed indicators and unobserved latent variables and the structural model defines relationships among the unobserved latent variables.

As there is no observed endogenous (dependent) variable and only one latent endogenous (dependent) variable, the equations for the measurement model are as follows:

$$x = \Lambda_x \xi + \delta$$

where x = vector of observed exogenous (independent) variables,

ξ = vector of latent exogenous (independent) variables,

Λ_x = regression matrix of X on ξ ,

δ = vector of measurement errors in X ,

The structural model in this study includes four exogenous latent variables ξ and one endogenous latent variable η . The

η variable is construction site safety. The ξ variables are individual factor, object factor, environment factor, and management factor. The equation for the structural model is as follows:

$$\eta = \Gamma \xi + \zeta$$

Where η = vector of latent endogenous (dependent) variables,

Γ = matrix of coefficients that relates exogenous factors to endogenous factors,

ζ = vector of residuals representing errors in the equation relating ξ and η

The proposed model was illustrated in Fig. 1.

3.2.1 Test of overall fit of the model

This paper adopts four indices, namely chi-square, root mean square error of approximation (RMSEA), comparative fit index (CFI) and the goodness of fit index (GFI) and normed fit index (NFI) to judge the fit of the hypothesized model to the data [12].

A small, non-significant chi-square value shows that the observed data are not significantly different from the

hypothesized model, and the lower the chi-square value, the better the fit. RMSEA measures the lack of fit per degree of freedom, and a value of 0.08 or less would indicate an acceptable error of approximation. CFI of .90 or greater is an indicative of a good fit. NFI index compares fits of two different models (the hypothesized model and the null model) to the same data set, and NFI of .90 or greater indicates an acceptable fit to the data. The goodness of fit indices for the proposed accident path model run (Fig. 1) is shown in Table 1. The results indicate that the proposed model is a good fit to all of the data.

TABLE I
 GODNESS OF FIT INDICES FOR THE PROPOSED MODEL

Indices	Chi-square	RMSEA	CFI	NFI
MG	1236.34	0.0735	0.912	0.021
WG	1073.28	0.0726	0.923	0.031
CG	1425.17	0.0685	0.901	0.052

3.2.2 Result of the structural model run

The results of the proposed cause model from the three viewpoints are shown in Fig. 2., Fig. 3 and Fig. 4 respectively.

According to the result of the structure model, the relationships among the safety of construction site (S) and the four aspects of factors from all the three parties (MG, WG, CG) are as follows:

$$\text{MG: } S = 0.93\xi_1 + 0.73\xi_2 + 0.74\xi_3 + 0.89\xi_4$$

$$\text{WG: } S = 0.78\xi_1 + 0.82\xi_2 + 0.65\xi_3 + 0.87\xi_4$$

$$\text{CG: } S = 0.91\xi_1 + 0.95\xi_2 + 0.72\xi_3 + 0.92\xi_4$$

The weigh allocation of the four aspects of factors path coefficient from all the three parties are as follows:

$$\text{MG: } \xi_1 : \xi_2 : \xi_3 : \xi_4 = 0.283 : 0.222 : 0.225 : 0.271 \quad (1)$$

WG:

$$\xi_1 : \xi_2 : \xi_3 : \xi_4 = 0.250 : 0.263 : 0.208 : 0.279 \quad (2)$$

$$\text{CG: } \xi_1 : \xi_2 : \xi_3 : \xi_4 = 0.260 : 0.271 : 0.206 : 0.263 \quad (3)$$

According to weigh allocation of the four aspects of factors, managers think that low quality of workers is the main cause of accidents on site, and the second one is the management problem. While workers consider the management problem as the most important attribute, and followed by the object factor. Clients treat the unsafe situation of object as the prime cause of accidents on site, and followed by the lack of management and low quality of workers.

All of the three parties think that lack of management is one of the most important attributes to poor construction site safety in China, however, there are many distinctive differences about the importance of each factor. Managers are likely to attribute the poor situation of construction safety to workers, neglecting the unsafe situation of object. Both of the workers and CG have recognized the poor situation of object, considering that many serious accidents on construction site are related to low quality of material.

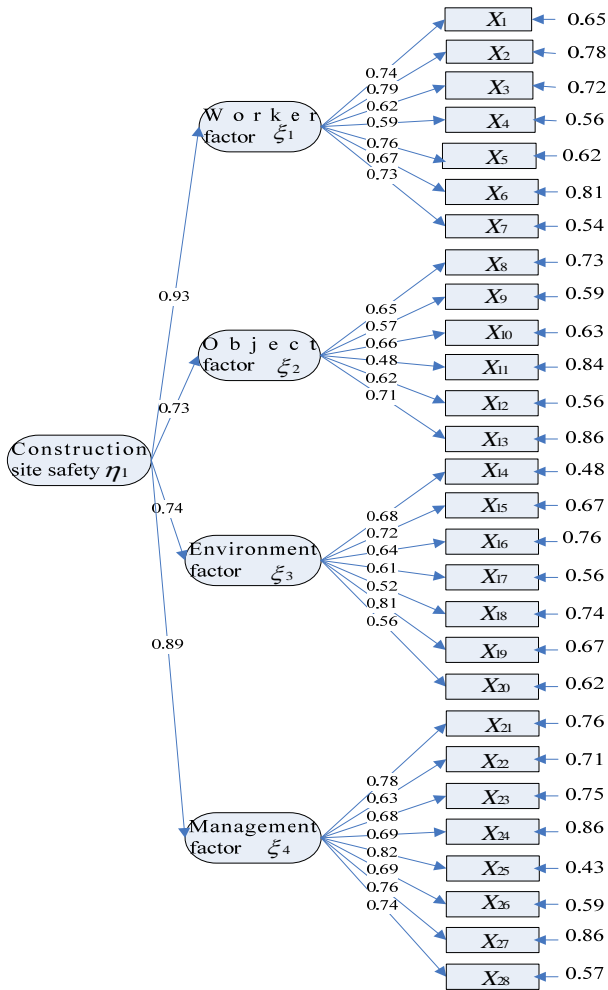


Fig. 2 Path model from the viewpoints of managers

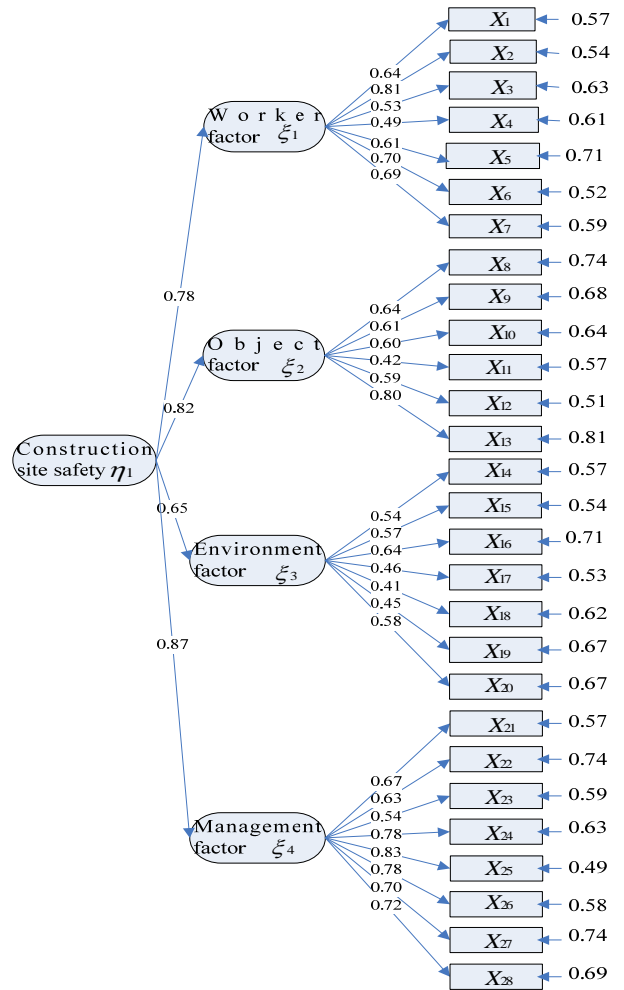


Fig. 3 Path model from the viewpoints of workers

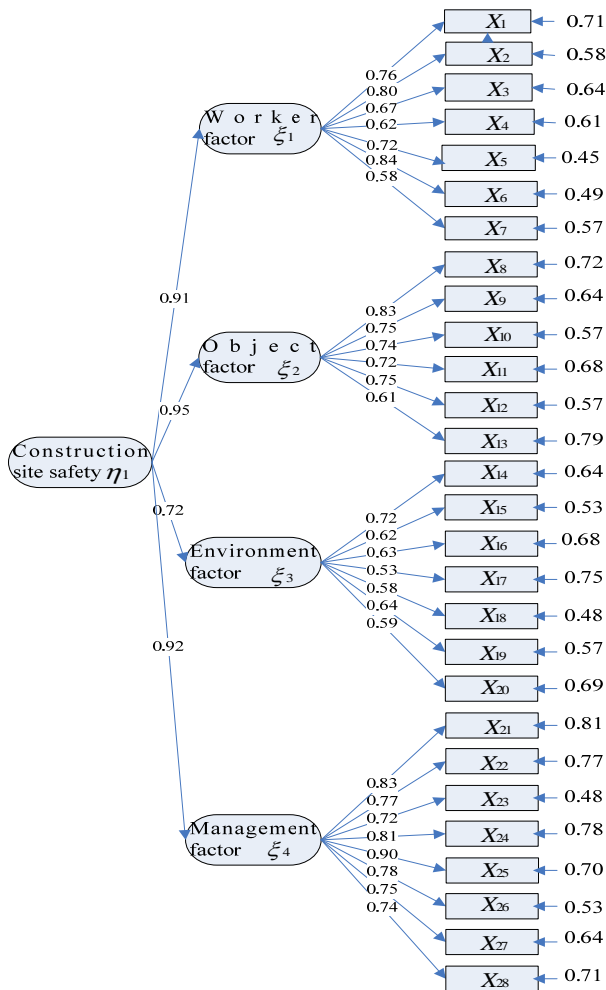


Fig. 4 Path model from the viewpoints of clients

IV. CONCLUSIONS

Construction safety in China is of great concern to construction managers, workers, government and other parties related to construction and it is needed to find the key causes of poor construction safety from the viewpoints of different parties. In views of the existing researches, this paper establishes the cause system of the poor construction site safety based on Delphi Method and then investigates the key aspects of these causes utilizing SEM from different parties, which would be instrumental in finding the obvious differences among them and making corresponding training and improvement for construction enterprises in China. According to the context, we may draw the following conclusions:

- 1) All the causes that affect the construction site safety can be re-sort out into 4 aspects, namely worker, object, environment and management. And all these four aspects of factors are causes of poor construction site safety in China.
- 2) In terms of the importance of each aspect of factor, different parties have different viewpoints. All of the three parties recognize that lack of management is one of the critical causes of poor construction site safety. And both of the managers and clients think that low quality of construction workers is one of

the vital causes of poor construction site safety while workers themselves have not realized the problems they have. Both of the workers and clients have noticed the object factor is still a problem to construction safety, while managers don't pay much attention to it.

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