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An Assessment Model of Owner Safety Management and Its Application to Real Estate Projects

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Abstract

Establishing a scientific and applicative safety management assessment system is crucial in improving safety performance of organizations. Currently, there are few studies on owners' safety management assessment systems. Based on the behavioral-based safety theory, this paper explores the links among safety management system, safety management behavior, safety management state and safety performance, which constitute an assessment model that characterizes the features of safety management. It then proposes a safety management indicator system that applies to real estate owners. The applicability and effectiveness of the system is verified by a four-year case study with a real estate owner. Relationships between safety management system, safety management behavior, safety management state, and their main impacting factors are obtained. Results indicate that the assessment model makes safety evaluation clearer and demonstrates significant correlations between different safety management issues. Owners' safety management system is established and implemented favorably under the safety management assessment indicator system. This paper presents a profound understanding of safety management assessment, in which the safety management assessment model and the indicator system is applied effectively in practice. To improve safety management level, specific theoretical and practical implications lead researchers and practitioners to pay more attention to safety management assessment.

Keywords: *safety management, assessment model, indicator system, real estate owner, case study*

1. Introduction

Real estate plays a fundamental role in the Chinese economy. In 2014, the investment and construction gross area reached RMB 95.036 trillion and 726,482 square meters, respectively (NBSC, 2014). However, the safety issues that occur during the real estate construction remain severe. A total of 648 workers have died as a result of 522 accidents in municipal building projects (MOHURD, 2014). These construction accidents bring huge losses for enterprises and individual workers. Different from the manufacturing and service industries, the real estate industry has a complex safety management structure. Temporary management teams are organized under various stages of the real estate construction project and include the owner, the contractor, and subcontractors, among others. In a construction project, when taking their defined responsibilities, all of these related parties play an important role in preventing and reducing the number of accidents. A considerable amount of literature on construction had demonstrated that the owner has a great influence on project safety management. Blair (1996) advocates the concept of comprehensive safety management in which all related parties should be responsible for safety in construction projects, especially the owner. Hinze (1996) argues that the main reason for frequent accidents in the construction industry is that safety is merely viewed as the responsibility of the contractor. Jawaharnesan and Price (1997) further demonstrate that the owner should frequently participate in safety management activities, whose effective measures will play an important role in improving safety performance. Research conducted by Toole (2002) shows that, expect for the owner, the related project parties all consider that both the owner and the contactor should undertake the main safety responsibilities. Among all parties of construction projects, owners hold the greatest leverage, which is first and foremost the leadership and authority to influence the behavior of other stakeholders, and thus can be regarded as project senior leaders (Construction Users Roundtable, 2012). Owners who take a proactive role in safety can significantly influence the safety experience on a construction project (Gambatese, 2000).

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Owners' involvement, including both participation and leadership, is especially important when the construction firm is not fully committed to safety (Hinze, 2006). Considering the significant role of owners in safety management, an indictor system of the owner's safety management assessment that is based on the construction of the owner's safety management system should be established. It is highly important to evaluate and enhance owners' safety management to improve safety performance during project execution.

Most enterprises measure safety management through a safety management assessment system that aims to identify unsafe or harmful factors and perform a risk evaluation by analyzing the actual safety management conditions of enterprises (Redinger *et al.*, 2002). Such a system can also evaluate the actual levels of organizational safety management from the perspective of the overall organization, and thus, the unsafe behaviors and defects that exist in organizations can be identified (Lu and Huang 2012). A number of studies have attempted to investigate safety management assessment in various industries, such as construction, aviation, and mining (Wang, 2006; Shyur, 2008; Lu and Huang, 2012). Based on a Bayesian network, a safety assessment system is developed for the construction site. This system consists of a series of safety and health performance indicators that conduct a performance assessment for occupational safety and health on sites (Cheung, 2004). Liou and Tzeng (2007) quantify the factors that affect aviation safety (i.e., management, operation, the environment and air control), and then develop a comprehensive assessment model that combines decision-making and evaluation models. Chen and Ma (2014) propose a comprehensive assessment model for coal mine safety based on uncertain random variables, and a simple case is utilized to validate this evaluation method. However, these studies do not indicate the hierarchical relationships among each of the indicators in the assessment model, and the classification of safety management assessment elements is not comprehensive. The approaches to improving safety performance remain unclear. Safety management assessment is an essential part of a safety management system because it provides the main information on the system's quality in terms of development, implementation and results (Sgourou *et al*., 2010). However, safety management assessment researchers typically focus on the evaluation methods (Hermans *et al*., 2008; Shen *et al*., 2009; Wu *et al.*, 2015), and the relationships among the safety management system and the other factors within the organization (such as organizational behavior) are rarely taken into account. Thus, it is essential to develop a new safety management assessment system that can evaluate enterprises' safety management levels in a more comprehensive and systematical manner (Jaselskis, 1996; Chang, 2009).

The owners' safety management assessment indicator system is established in consideration of the assessment model of safety management based on this research, which determines the relationships among the safety management system, safety management behavior, and the safety management state. This indicator system is applied over a four-year period in a real estate enterprise in China. The evaluation data are analyzed using correlation analysis and regression analysis to identify the existing safety problems and interactive relationships among the different assessment indicators. The validity and applicability of the safety management assessment system are verified according to the analytical results, and meanwhile, safety risk management measures are also proposed for owners.

2. Safety Management Assessment Model and Indicator System

This section introduces the process of establishing the safety management assessment model and indicator system for construction owners. First, the components of the safety management assessment model and the relationships among them are analyzed, and then, the model is proposed. Second, the performance of the safety management assessment indicator system is expounded.

2.1 Components of the Safety Management Assessment Model

2.1.1 Safety Management System

A safety management system is used to formulate a series of interrelated or interactive elements for establishing the policy and goals of occupational safety and health and then to achieve these goals (Machida and Bachoo, 2001). Its degree of perfection has an important influence on the systematic performance of safety management, which in turn determines the level of an enterprise's safety management. The practice of a safety management system not only reflects the organization's commitment to safety, but is also recognized as an essential component of employees' perceptions of the importance of safety in their company (Fernandez-Muniz *et al*., 2007). The safety management system is the basic guarantee for owners' safety modern management mode, which includes the scientific analysis, standardization and institutionalization of safety production management.

2.1.2 Safety Management Behavior

Safety management behavior is a set of working methods and their implementation process for accident prevention and accident loss control. It can be divided into organizational behavior and job behavior. Organizational behavior involves the perfection level or running situation of the safety culture and safety management system of organizations. Individual behavior involves employees' personal behavior (Fu, 2013), especially the individual behavior of employees in the organization's key position, which is also defined as job behavior. There is a close relationship between organizational behavior and job behavior (Wicks, 2001). Organizational behavior promotes the implementation of job behavior, and in turn, job behavior is the manifestation of organizational behavior. Based on the requirements of the safety management system, owners' organizations and all staff members at all levels comply with the relevant safety regulations, which in turn has an important influence on safety performance.

2.1.3 Safety Management State

The safety management state is the representation of organizational safety performance and the essential reflection of the safety management system and safety management behavior. According to the general elements of safety management, the safety management state is the extent to which safety requirements are satisfied from the dimensions of the individual, the object and the environment in material conditions and the work order (Hofmann and Stetzer, 1996). Unfortunately, the currently existing safety assessment invariably focuses on the construction site and thus cannot directly reflect the cause of the owner's safety management problems. There are many possible reasons for the adverse safety state of the construction site, such as a lack of preventive measures against safety problems, contractors' noncompliance with safety regulations, and owners' rare participation in safety management on construction sites. The absence of accurate reasons for accidents hinders a targeted improvement after a safety assessment for owners. Hence, assessing the safety management system, safety management behavior, and the safety management state simultaneously is important for identifying the existing safety problems.

2.1.4 Safety Performance

Safety performance is the effective output of organizations that are attempting to fulfill their objectives at different levels and the results of organizational expectations (Cree and Kelloway, 1997). Safety performance is indicative of not only the degree of damage to lives, property and the environment as a result of accidents but also the efficacy of the implementation of safety management behavior and the orderly character that the safety management state should present (Sgourou and Katsakiori, 2010). Assessing safety performance is an effective measure for implementing the safety responsibilities of real estate owners. On the basis of indicator requirements, the levels of safety production performance should be regularly reviewed at the managerial level.

2.2 Safety Management Assessment Model

According to accident-causing theory, unsafe behavior and the unsafe status of objects are the direct causes of accidents, whereas defects in management are the indirect cause (Bird, 1984). Many researchers consider that human factors play a very fundamental role in improving organizational safety performance (Donald and Young, 1996; Oliver *et al.*, 2002). Employees are the last line of defense against risks. Their behaviors are crucial for avoiding personal injury and material damage (Eiff, 1999; Hofmann and Stetzer, 1996). According to statistical analysis, most accidents are attributed to the unsafe behaviors of workers, which are often caused by potential flaws in organizations and management systems (Kawka and Kirchsteiger, 1999; Perrow, 1984; Reason, 1997). Therefore, job behavior and the safety management state are the direct factors of safety performance.

In accident investigations, individuals who are directly involved in accidents tend to be more easily accused. However, organizational factors (such as the safety management system, processes, supervision, and guidance) are often neglected (Fang and Wu, 2015). Wilpert (1994) stresses that many accidents are generally not caused by a single operator but occur as the results of a series of interactive factors at various levels of the organization. This perspective holds the view that accidents that are attributed to errors typically have their true roots in organizational management and the system design (Fernández-Muñiz *et al.*, 2014). Thus, the safety management system and organizational behavior determine job behavior and the safety management state and have an indirect influence on safety performance.

Many researchers regard errors more as consequences than as causes, which suggests that organizational factors influence the safety outcomes via workers' behavior (DeJoy, 1994; Brown *et al.*, 2000; Hofmann and Stetzer, 1996). Organizational behavior theory argues that job behavior is determined by organizational behavior (DeJoy, 2005; Hersey, 1988), and the organizational behavior reflects the level of the organizational culture and management. As a consequence, the safety management system determines the implementation of safety management behavior; they both promote the safety management state. Meanwhile, the safety management state reflects the implementation effect of safety management behavior and the maturity of the safety management system.

A safety management assessment model is established based on analyzing the conceptions and relationships of safety management elements. Providing enterprises' safety management assessment with assessment elements, the safety management assessment model is the basis of a reasonable and effective safety management assessment indicator system and makes the performance of the safety management assessment more logical and systematic.

By confirming the relationships among the safety management system, safety management behavior, the safety management state and safety performance. Fig. 1 shows the safety management assessment model.

2.3 Performance of the Assessment Indicators

2.3.1 Assessment Indicators of the Safety Management System

Taking the example of the process of running an occupational health and safety management system, the safety management system in this research is built according to the "Set guidelines

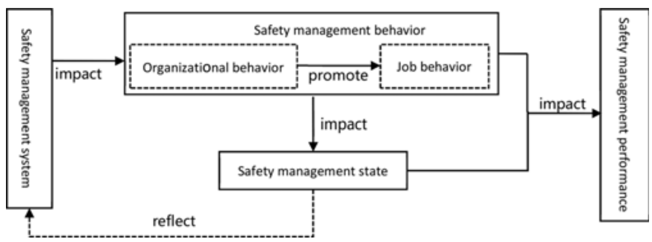

Fig. 1. Assessment Model of Safety Management

→ Plan → Implement and run → Check and correct→ Management review" procedure (Pinto *et al*., 2011). On the basis of the establishment of the organization's safety policy, enterprises should set safety goals and decompose their safety work plans. Establishing a safety organization structure and defining the safety responsibility of each personnel position are similarly indispensable. The continuous improvement of the safety management system can be achieved through operation mechanisms such as safety culture development, safety investment protection, safety education and training, stakeholder management and emergency rescue. Simultaneously, the implementation of measurement and remedial actions such as safety supervision and inspection, compliance evaluation, safety accident management and performance evaluation is overwhelmingly crucial (Choudhry *et al*., 2006).

Therefore, five assessment indicators that belong to the safety management system are extracted based on the systematic process and comprehensiveness of the safety management system (Bhanupong *et al*., 2016; Leyla *et al.*, 2015; Eva and Vaidotas, 2010; Josef and Eber, 2014; Daniel, 2015): (1) the safety goal and plan include the safety production goal and the safety production plan, which contribute to the attainment of the goal; (2) the safety agency and personnel are the condition for leading organizations and supervisory organizations of safety production and safety management staffing; (3) the safety responsibility and system involve the assignment of safety production responsibility at the managerial level and the grassroots level and safety management regulations that benefits safety work; (4) the safety mechanisms and guarantee entail management methods for safety management work; and (5) the emergency plan and system involve the preparation of personnel, equipment and the contingency plan for emergencies.

2.3.2 Assessment Indicators of Safety Management Behavior

2.3.2.1 Safety Management Organizational Behavior

The organizational behavior of safety management is the specific process of performing the safety management system (Wilson, 1989). Under the guidance of safety policy and regulations, organizations should ensure management for the organization and personnel and devote attention to the construction of an organizational safety culture. Similarly, organizational behavior includes education, training, supervision, inspection, the performance of the capital investment and the strengthening of risk control through accident management and emergency rescue management (Choudhry *et al*., 2006).

Therefore, there are eight second-level indicators built to evaluate safety management organizational behavior from the perspectives of the implementation of responsibilities and risk prevention (Bhanupong *et al.*, 2016; Josef and Wolfgang, 2014; Hany *et al*., 2013; Daniel, 2015; Essam *et al.*, 2012; Zhou *et al*., 2014): (1) compliance with safety regulations is the abidance of safety legislations, regulations and criteria for enterprises; (2) the implementation of safety responsibility means that the process and effects of safety responsibilities are distributed to different personnel and departments; (3) the construction of a safety culture is the guideline of overall safety work and the methods of promoting personnel's safety quality, characterizing enterprises' belief in safety; (4) safety education and training are the educational work for raising safety awareness, learning safety knowledge, and improving safety skills; (5) safety supervision and inspection entail the supervisory behaviors of making safety responsibilities practical, implementing safety regulations, and tracking down and eliminating safety hazard; (6) the safety capital investment is the fund that promotes safety management work and improves the safety production condition; (7) emergency rescue management indicates that organizational behaviors, in the stages of prevention, preparation, reaction and recovery, are beneficial for tackling possible major accidents or emergencies and reducing the consequences of accidents; and (8) safety accidents management is the process of collating information on accidents, analyzing the causes of accidents and proposing prevention measures.

2.3.2.2 Safety Management Job Behavior

An organization is divided into the decision-making level, managerial level and the grassroots level (Luria and Morag, 2012). Consequently, the job behavior assessment indicators can be set based on these three levels. According to the scope of the organization evaluated, the three levels divided from the macro perspective can correspond to specific jobs:

- The decision-making level leads the construction of the safety culture, which impacts the setting of safety goals and plans and plays a vital role in establishing the organization's safety policy. It also influences the willingness for safety investment and support for safety work.
- The managerial level needs to correctly understand the intention of the decision-making level according to the assignment of responsibilities to each department in the organization. Managers command and supervise the staff of the grassroots level to complete tasks that combine with the requirements of the departmental job (Conchie *et al.*, 2013).
- The grassroots level is the real performer of the organization's safety policy, safety objectives and safety plans. The safety awareness, safety levels and safety behaviors of the staff at the grassroots level directly determine the status and performance of the organization's safety management (Hee-Chang *et al*., 2015).

This safety management assessment system specifies the decision-making level, the managerial level and the grassroots level as the regional company, the urban company, and the projects department, which includes projects under construction and the property management section, which involves civil residential property and commercial property.

2.3.3 Assessment Indicators of the Safety Management State

The safety management state assessment indicators are set according to the facets of the person, the object and the environment (Hinze *et al*., 2013). The safety management state of the person

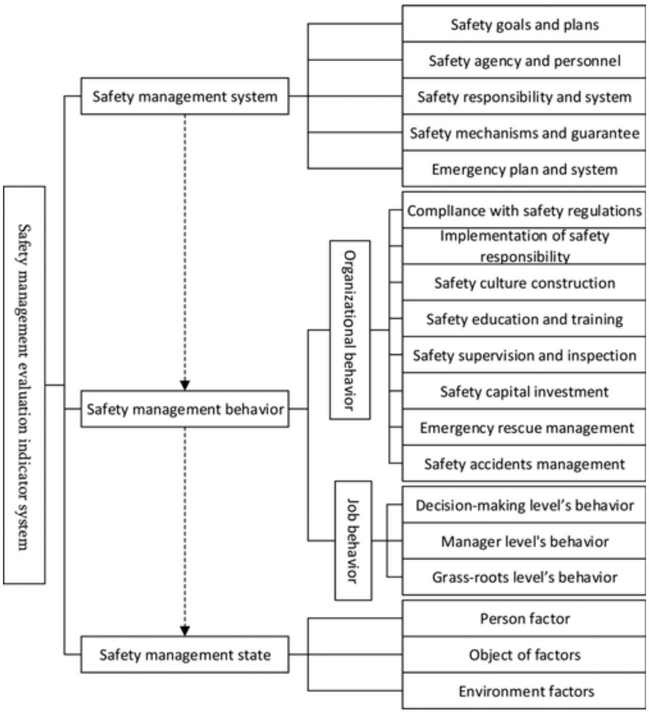

Fig. 2. Indicators System of Safety Management Assessment

mainly refers to the external safety state of command, operation, defense, etc. (Duff *et al.*, 1994), which also includes the internal safety state (psychological state) such as laziness, impatience, conformity, paralysis, and contravention (Hoyos, 1992). The safety management state of the object is the degree of maturity of condition factors such as different workplaces, technology, equipment and facilities. It similarly reflects the adaptability and coordination between the person factors and the object factors. The environment factor mainly refers to the operating environment and working atmosphere under the influence of safety management behavior (Zhou *et al.*, 2008; Vivian *et al.*, 2006).

2.3.4 Indicators System of Safety Management Assessment

Summarizing the indicators noted above, Fig. 2 shows the safety management assessment indicator system. The indicators system regards the safety management system, safety management behavior and the safety management state as first-level indicators, which altogether include nineteen second-level indicators. In addition, safety management behavior includes organizational behavior and job behavior.

3. Case Study on the Real Estate Owner

To prove the validity and reliability of the above safety management model (Fig. 1) and its indicator system (Fig. 2), a case study in a Chinese listed real estate enterprise that has eight regional companies containing several city subsidiaries and more than one hundred projects across the country was conducted. To improve the overall level of safety production management, this enterprise (owner) conducts an annual safety performance assessment for its eight regional companies (hereinafter referred to region) based on the aforementioned safety management assessment indicator system. This section analyzes the annual evaluation data of every region from the year of 2011 to 2014 based on statistical analysis to verify the validity and reliability of the safety management indicator system. Simultaneously, this research also explores the relationships among the different indicators and their degrees of impact on safety performance.

3.1 The Method of Safety Management Assessment

According to the characteristics of the house construction projects, there are 97 third-level indicators and 441 fourth-level indicators (detailed assessment items) based on the high-level indicators. The basis of selecting the third and fourth indicators covers three layers: 1) The safety requirements of safety legislations of Chinese construction industry. 2) The higher-level company's safety stipulation. The higher-level company's safety stipulations are always stricter than the legislations of national level. 3)The excellent practices of other real estate enterprises. So many indicators are too hard to show to readers. Thus, the authors take an example of third and fourth indicators (Table 1). Each fourth-level indicator is scored in the evaluation process. When the scores of all fourth-level indicators are given, the scores of the third-level indicators, the second-level indicators, the first-level indicators and the total scores are successively calculated by specific scoring rules. In this project, safety assessment project using integrated approach to carry out. The approach includes personnel interview, safety document review and on-site inspection. Personnel interview aims to realize safety awareness and the safety participation degree of managers. As well as, the supporting documents are the necessary inspection items. Reviewing the safety document is to evaluate the perfection degree of safety management system files and records of safety management behavior. The indicators of safety management state are evaluated by on-site inspection. The score of each fourth-level indicator is given according to the corresponding regulations of

Table 1. Partial Content of Indicators System

Second indicator	Third indicator	Fourth indicator
Safety goal and plan	Safety goal	1) Confirming the region company's long-term and annual safety goal. The goals should be clear, practicable and measurable. 2) Safety goal should be gradually resolved and carried out to each related department.
	Safety plan	1) Formulating the safety plan on the basis of safety management analysis. Safety plan should be associated with safety goal and concrete. 2) Analyzing fulfillment of safety goal and plan in every quarter of a year, as well as the key point of the next stage.

Table 2. Calculation Method of Indicators' Score

Third-level indicator (H1)	Fourth-level indicators (L1, L2, L3)		
Score (centesimal)	Weighted score	weight	Score (centesimal)
76 (H1)	30	30%	100 (L1)
	16	20%	80 (L2)
	30	50%	60 (L3)

Table 3. Scoring Rules of Detailed Assessment Items

Scoring percentage	Description
100%	Inspection results comply with the requirements of the assessment standard system totally and the implementing of requirements do well in any aspects and time.
80%	In most cases, inspection results conform to the requirements of the assessment standard system, and have more excellent practices.
60%	More than half inspection results conform to the requirements of the assessment standard system, just reaching the pass-line.
40%	A small number of inspection results conform to the requirements of the assessment standard system.
20%	A majority of inspection results do not conform to the requirements of the assessment standard system, related departments are just ready to make efforts
0	Inspection results do not conform to the requirements of the assessment standard system completely, related departments have no consciousness about the safety work

the scoring proportion and the degree to which the actual performance level conforms to the evaluation standard system (Table 2). The first-level and second-level indicators can be calculated by same manner. Table 3 shows the scoring rules of the detailed assessment items in the indicator system.

In the owner's safety management assessment indicator system, the weights of the indicators depend on their relative importance. In the following section, the weights of the indicators are determined by means of an expert focus group meeting.

Table 4. Calculating Rules of the Score of Safety Management Evaluation

Assessment indicators		Weight		Score	
Safety Management System		20%		20	
Safety Management Behavior	Organization Behavior	40%	50%	20	50
	Job Behavior	60%		30	
Safety Management State		30%		30	
Total score				100	

(1) Weights of the first-level indicators. Safety management behavior has more influence on safety performance than the safety management system and safety management state, which can directly reflect the safety condition. Meanwhile, the assessment of job behavior is more beneficial to ascertaining the safety management responsibilities of the owner's staff. Consequently, experts determine that the first-level indicators' percentage scores are 20%, 50%, and 30%.

(2) Weights of the second-level and third-level indicators. There is almost no assessment of safety management by the owner, and therefore, in practice, this assessment system adopts simple settings for the indicators. The experts suggest equalizing the weights of the second-level indicators so that they are the same as the first-level indicators. The weights of the third-level indicators depend on their level of importance. The items that are not involved and the individuals who are not interviewed are treated by default.

Table 4 shows the scoring rules of safety management assessment. Table 5 shows the introduction of experts group.

According to each region's real estate score, the safety production management performance and risk levels are classified. Then, each risk level is described with one color to refer to the risk evaluation index and the risk matrix (Eskesen and Tengborg,

Table 5. Participants in This Study

Expert sources	College	Region company	Headquarters company	Main contractor	Supervising unit	Government safety departments
Number	3	1	2	2	2	1
Position	Professor and associate professor	Head of the department of health and safety	Head of the department of health and safety	Chief safety manager	Chief safety manager	Head and deputy heads of the construction division

Table 6. Risk Evaluation Index and Risk Matrix Of Accidents

Probability rating	Severity rating			
	I (disastrous)	II (serious)	III (mild)	IV (slight)
A(frequently)				
B(probably)				
C(sometimes)				
D(rare)				
E(impossible)				

Table 7. Division Standard of Risk Grade for Safety Production Management

Scores range	Warning colors	Risk grades	Rectification requirements
90~100		Excellent	Continuous improvement
75~90 (contain 90)		Good	Needs to be improved
60~75contain (60 and 75)		General	Rectify within a time limit
0~60		Poor	Rectify immediately

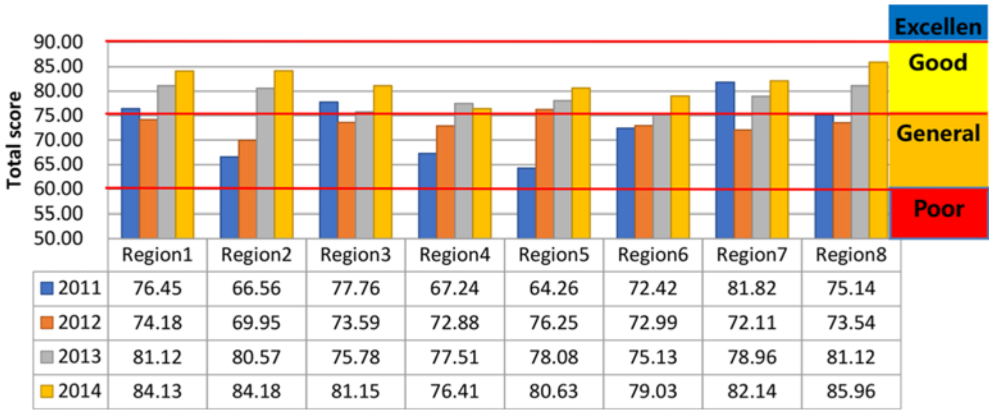

Fig. 3. Four-year Total Score of Each Region

2004). Finally, the corresponding measures and suggestions are proposed according to the risk levels. Table 6 shows the risk evaluation index and the accident risk matrix.

The evaluation results of risk matrix:

(1) , Acceptable: The safety level is in an acceptable range.

(2) , Critical: The safety situation is on the verge of emergency, casualties or property losses, whose causes are not temporary. The enterprise should eliminate the risk and take measures.

(3) , Dangerous: Casualties or property losses can be caused, and the enterprise should take immediate measures.

(4) , Unacceptable: Catastrophic accidents can be caused, and safety hazards must be immediately eliminated.

According to the colors in the evaluation results of the risk matrix, the risk grade and warning colors are determined, and the corresponding rectification requirements are proposed (Table 5).

As shown in Table 7, safety risks are divided into four levels with different warning colors that represent the corresponding score range. This scheme is a straightforward approach for the enterprise to compare the safety management levels of different projects. In addition, the risk grades can give a clear warning of actual safety management situation for the regions that have been evaluated. Using this method, the enterprise will pay more attention to safety management and focus on eliminating the defects in management.

It is indispensable to indicate that, taking the characteristics of diverse owners and projects into account, adjustments to the second-level indicators, the third-level indicators and the assessment details are also necessary. The first-level indicators' weights and range of scores of the risk grades should be set according to the emphases of safety management assessment.

3.2 Analysis of the Results of the Safety Management Evaluation

In this section, the variation tendency of the overall level of safety management is analyzed by comparing the four-year score changes of the 8 regions. Then, owners can summarize the safety production experience and the effective safety management measures to improve the safety performance. Fig. 3 presents the total score of the safety management assessment for each region over the past four years.

As shown in Fig. 3, from 2011 to 2014, total scores of regions 2, 5 and 6 are on the rise. The total scores of regions 1, 3, 7 and 8 in 2012 are higher than those in 2011, rising in 2013 and 2014. The total scores of region 4 rise from 2011 to 2013 but decline in 2014. According to the range of scores, the safety management level warning colors of the 8 regions are distributed in the areas of orange and yellow, which are at average or good levels. No region succeeds in reaching the excellent level, which illustrates that, in safety production management, they have much room to improve.

To obtain the owner's safety production management levels for each first-level indicator, the four-year average scores of each first-level indicator (the safety management system, safety management behavior and the safety management state) of each region are contrasted (see Fig. 4).

As shown in Fig. 4, there are four regions whose average

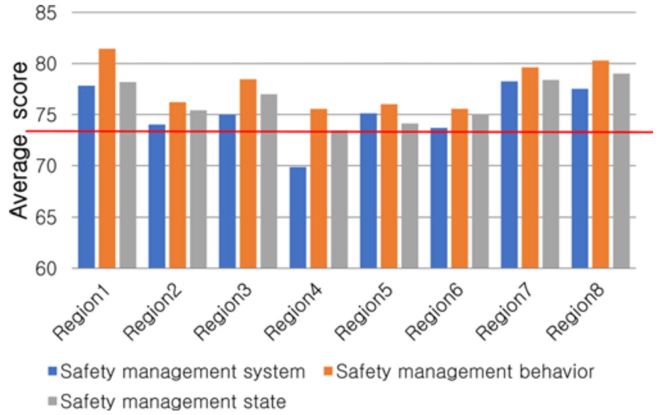

Fig. 4. Four-year Average Scores of Each First-level Indicator of 8 Regions

Table 9. Test of Homogeneity of Variances

Levene Statistic	df1	df2	Sig.
.102	2	21	.903

Table 10. Analysis of Variance

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	30.145	2	15.072	2.566	.101
Within Groups	123.364	21	5.874		
Total	153.508	23			

safety management system scores are in the range of 75 to 80, which are graded as good. The average scores of the other four regions are less than 75 points, which are graded as average. The data show that the safety management system levels of the different regions are uneven and that there is a large gap between the regions. The average safety management behavior scores of each region are all graded as good, which indicates that the overall condition of safety management behavior is better than that of the safety management system. However, the scores of only region 1 and region 8 are greater than 80 points, which suggests that safety management behavior still needs to be further improved. There are six regions whose average safety management state scores are graded as good, and two regions are graded as average, requiring rectification within a time limit.

In this section, a comprehensive analysis for the four-year results of the safety management assessment is conducted. By comparing the total scores of each region and the average scores of each first-level indicator, the owner can grasp the variation trend of the safety management situation. In this manner, the defects in the owner's management can also be determined. Furthermore, the enterprise can obtain the risk grade of each indicator through a safety management assessment to improve in weak areas with clear targets.

3.3 Variance analysis

To further analyze the relationships of interaction between the safety management system, safety management behavior and the safety management state, the variance of their four-year average scores were analyzed first based on the evaluation data. In this section, SPSS 22.0 (Statistical Product and Service Solutions) was used to conduct the analysis through the technique of single factor variance analysis.

SPSS performed the Kolmogorov-Smirnov test on the average scores of every first-level indicator as sample data, and the results were as follows: $Z = 0.461$, $P = 0.984 > 0.05$. Thus, the null hypothesis cannot be overturned, and sample data were normally distributed and can be used to conduct the variance analysis. Table 8 reports the descriptive statistics of the three groups of sample data. Table 9 shows the homogeneity results of the variance test, and the significance level ($P = 0.903 > 0.05$) indicates that variance analysis is feasible.

Table 10 shows the F test results of the single factor variance analysis ($F_{(2, 21)} = 2.566$) and the significance level ($P = 0.101 > 0.05$). The results state that there is no significant difference among the evaluation scores of the safety management system, safety management behavior and the safety management state. They actually suggest that, for the different first-level indicators, the management levels of the real estate owner are relatively balanced.

3.4 Correlation Analysis and Regression Analysis of the Evaluation Data

To ascertain the degrees of correlations among the different-level indicators, the methods of correlation analysis and regression analysis were used by the SPSS software to analyze the four-year evaluation data.

Correlation analysis on the three first-level indicators (safety management system, safety management behavior and safety management state) was conducted. The Pearson product-moment correlation was used to calculate the correlation coefficient, and a unilateral test was selected. Table 11 shows the results.

Table 8. Description of Statistics

	N	Mean	Std.Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Safety management system	8	75.1525	2.76904	.97900	72.8375	77.4675	69.86	78.24
Safety management behavior	8	77.8887	2.35863	.83390	75.9169	79.8606	75.55	81.43
Safety management state	8	76.3288	2.09586	.74100	74.5766	78.0809	73.46	79.00
Total	24	76.4567	2.58346	.52735	75.3658	77.5476	69.86	81.43

Table 11. Correlation of Safety Management System, Safety Management Behavior and Safety Management Status

		Safety management system	Safety management behavior	Safety management state
Safety management system	Pearson Correlation	1	.910**	.797**
	Sig. (1-tailed)		.000	.005
Safety management behavior	Pearson Correlation	.910**	1	.913**
	Sig. (1-tailed)	.000		.000

Table 12. Multiple Regression Analysis of the Indicators Affecting Safety Management System

Predictors	Unstandardized Coefficients		Standardized Coefficients	t
	B	Std. Error	β	
Constant	-4.734	11.169		-.424
Safety goals and plans	.194	.118	.247	1.647
Safety agency and personnel	.005	.094	.004	.049
Safety responsibility and system	.123	.133	.116	.924
Safety mechanism and guarantee	.254	.146	.337	1.741
Contingency plan and system	.185	.067	.314	2.782
R = .996 R^2 = .992 Adjusted R^2 = .976 F = 61.668*				

*.P<0.05

The analytical results show that the correlation coefficient of the safety management system and safety management behavior is 0.910, which is highly correlated ($r > 0.8$). The correlation coefficient of the safety management system and the safety management state is 0.797, which is moderately correlated ($0.5 < r < 0.8$). The correlation coefficient of safety management behavior and the safety management state is 0.913, which is highly correlated. The three correlation coefficients are all significant at the 0.01 level. The results suggest that the degree of correlation of safety management behavior and the safety management state is the highest; and this finding also proves the rationality of the safety management assessment model (Fig. 1), in which safety management behavior has the decisive effect on the safety management state. The degree of correlation of the safety management system and safety management behavior is the second highest, which verifies that the safety management system has a direct promotional effect on safety management behavior. Moreover, the degree of correlation of the safety management system and the safety management state is the third highest, which similarly verifies that the influence of the safety management system on the safety management state is indirect.

To further determine the second-level indicators that have a main impact on each first-level indicator, that is, to identify the dominant factors that determine the effects of the safety management system, safety management behavior, and the safety management state, the technique of regression analysis was used. Analysis of linear regression was conducted to evaluate the effects of different owner practices on project safety performance as measured by the total recordable injury rate TRIR. It should be mentioned that in the regression analysis, TRIR was treated as a dependent variable, since the total number of projects at 100 is sufficiently large and the normality assumption and equal variability assumption are roughly satisfied as discussed in subsequent paragraphs.

First, the regression analysis of the safety management system and its second-level indicators was conducted, setting the TRIR as the dependent variable and the safety management system's second-level indicators as the independent variables. Table 12 shows the results.

The results in Table 12 indicate that the multiple correlation coefficient R of the independent variables and the dependent variable is 0.996, the coefficient of the determination $R^2 = 0.992$ and the adjusted $R^2 = 0.976$. These findings indicate that these six variables can explain 97.6% of the variance of the safety management system. Then, according to the comparison of the standardized regression coefficient β, the "safety mechanisms and guarantee" ($\beta = 0.337$), the "contingency plan and system" ($\beta = 0.314$) and the "safety goals and plans" ($\beta = 0.247$) are the three second-level indicators that have the largest effects on the safety management system.

Second, this section conducts a regression analysis on the relationship between TRIR and safety management behavior's second-level indicators. The second-level indicators that have strong correlations ($r > 0.7$) between each other were previously removed. Then, the remaining indicators were regarded as independent variables, and safety management behavior was the dependent variable. Table 13 shows the results of the regression analysis.

The results in Table 13 report that the independent variables entering the regression model can explain 97.6% of the variance of safety management behavior. Additionally, according to the comparison of the standardized regression coefficient β, the indicators that have the largest effects on safety management behavior are the "implementation of safety responsibility" ($\beta = 0.333$), "safety education and training" ($\beta = 0.262$) in organizational behavior, the "job behavior of the decision-making level" (β =

Table 13. Multiple Regression Analysis of the Indicators Affecting Safety Management Behavior

Predictors	Unstandardized Coefficients		Standardized Coefficients	t
	B	Std. Error	β	
Constant	-8.061	25.774		-.313
Safety education and training	.099	.073	.262	1.354
Implementation of safety responsibility	.127	.384	.333	.071
Safety capital investment	.078	.189	.094	.416
Emergency rescue management	.065	.185	.085	.349
Safety accidents management	.088	.106	.160	.829
Job behavior of decision-making level	.264	.166	.428	1.591
Job behavior of manager level	.086	.135	.125	.636
Job behavior of grass-roots level	.397	.287	.396	1.381
R = .907 R^2 = .823 Adjusted R^2 = .796 F = 23.307*				

*.P<0.05

Table 14. Multiple Regression Analysis of the Indicators Affecting Safety Management Status

Predictors	Unstandardized Coefficients		Standardized Coefficients	t
	B	Std. Error	β	
Constant	71.393	55.182		1.294
Supervising units fulfill responsibility	.588	.903	.468	1.094
Special operation management	.058	.257	.056	.224
Safety management of facilities	.392	.265	.165	.347
Dangerous operations management	.509	.632	.586	1.596
Decoration management	.445	.795	.487	.812
Fire control management	.234	.609	.316	1.535
Lift management	.041	.219	.058	.189
R =. 910 R^2 = .823 Adjusted R^2 = .801 F = 7.037*				

*.P<0.05

0.428), and "job behavior of the grassroots level" (β = 0.396).

Finally, the regression analysis of the relationship between the TRIR and safety management state's second-level indicators was conducted. The indicators that have a strong correlation with the safety management state (r > 0.8) but have a weak correlation with each other (r < 0.5) were entered into the regression model as the independent variables. The safety management state was the dependent variable. The results of the regression analysis are shown in Table 14.

As shown in Fig. 2 above, safety management state is divided into the state of the individual, the state of the object and the state of the environment. The safety management state of the real estate owner is mainly evaluated from these three dimensions. The management state of projects under construction and the management state of property projects are examined in detail. The independent variables in the regression model are selected through the correlation analysis. Table 14 reports that the seven independent variables can explain 97.6% of the variance of the safety management state. According to β, the indicators that have the largest effects on the safety management state are "responsibility fulfillment" (β = 0.468), "dangerous operations management" (β = 0.586), "decoration management" (property projects) (β = 0.487) and "fire control management" (projects under construction and property projects) (β = 0.316).

4. Discussion

4.1 Research Implications and Preventive Measures in Real Estate Construction

The statistical analysis of the data indicates that there is a correlation among the safety management system, safety management behavior and the safety management state. The correlation between the safety management system and safety management behavior is stronger than that between safety management behavior and the safety management state, though they are both highly correlated. The results confirm the correlation among the three assessment elements and the correlation among the different safety management issues. In previous studies, the safety management system includes the system document and implementation; however, in this paper, implementation falls under safety management behavior. The system document aims to ensure that implementation reflects the organizational safety potential and capacity to achieve its safety aspiration. This categorization not only ensures that the contents play different roles in the safety management system but also confirms the relevant reasons (the lack of the system document or the omission of implementation) in analyzing safety problems.

This paper makes two practical contributions: on the one hand, this safety management assessment indicator system identifies

Table 15. Hazards and Measures of the Main Indicators in the Safety Management System

Safety management system	Hazards	Corresponding measures
Safety goals and plans	• A lack of an instructive work plan, prominent content and execution in the main safety job. • Safety goals and plans are disconnected from practical work and are not performed in different functional departments.	• Formulating a safety work policy, deepening the classification targets that include the construction of the system and institution. Further, making them measurable and verifiable. • Indicating the specific approaches that involve the arrangement of staged and measurable tasks. There are concrete indicators for observing and improving the safety plan.
Safety mechanism and guarantee	• A lack of a standard assessment system. • The absence of systematic regulations on organizational implementation, content, and examination in safety education.	• Presenting a work plan and process of standard assessment, regularly maintaining and improving the safety management system. • Establishing an institution, compiling an annual plan, and arranging the costs of safety education and training and making them regularized, normalized and institutionalized.
Emergency plan and system	• An integrated emergency system and internal/external review record are missing • The applicability of the emergency system in an emergency drill is not verified.	• The emergency plan should conduct internal and external evaluations. The approval and issuance of the plan by the general manager in a reasonable manner. According to requirements, the manager reports it to corporate headquarters for recording. • By means of drills, continuously revising and improving the emergency plan to enhance its maneuverability.

Table 16. Hazards and Measures of the Main Indicators in Safety Management Behavior

Safety management Behavior		Hazards	Corresponding measures
Organizational behavior	Implementation of safety responsibility	• The safety accountabilities of different departments are ambiguous • The regulations of safety accountability do not conform to departmental characteristics.	• Further ensuring the accountabilities of safety organizations and personnel. • According to the features of the functional departments, implementing accountabilities of the safety organizations and security departments.
	Safety education and training	• Safety training lacks a detailed plan. • The examination and observation of the effects of safety training are not effectively performed.	• Establishing an institute of safety education and training, formulating an annual training plan, and implementing capital sources. • Enforcing the supervision of the training process, enriching the content of training, and examining the training effects.
Job behavior	Job behavior of the decision-making level	• The safety management mode and control do not meet the requirements, and the implementation of safety management is not deep enough.	• Implementing safety organizations and arranging staff to improve the establishment of the safety management system.
	Job behavior of the grassroots level	• Project departments under construction seldom perform safety management work systematically. • Very few staff members have sufficient safety knowledge at the grassroots level of the property project.	• Strictly meeting the requirements of the project department's safety management on site. • Enforcing safety training, popularizing safety knowledge and emphasizing safety motivation to enhance the staff's safety awareness and skill.

Table 17. Hazards and Measures of the Main Indicators in the Safety Management State

Safety management state	Hazards	Corresponding measures
Responsibility fulfilment	• The scaffolds on site are not brought into the supervisory scheme. • A lack of electricity distribution requirements in the temporary firefighting project.	• Based on related regulations, the requirements of enterprises, and the project business, organizing the contents of supervision scheme. Ensuring the details of firefighting and facilities. The responsibility of supervisors and supervisory work should be scheduled.
Dangerous operations management	• Laborers and spider-men have insufficient safety protection. • Combustibles are casually piled up, resulting in an adverse environment of electric-welding operations.	• Formulating regulations for high-place operations and protective equipment. • Formulating regulations on electric-welding operations and their examination and monitoring.
Decoration management	• Combustible decoration materials are casually piled up, and electric equipment is used incorrectly.	• Related departments should strengthen management of decoration personnel and safety inspection personnel, and construction principle should be regulated by the contractor.
Fire control management	• Equipment does not conform to firefighting plan. • A lack of firefighting experience.	• Equipping fire facilities according to the firefighting plan. Enforcing the institution of firefighting inspection, ensuring the responsibility and reviewing the inspection records

actual safety issues and risks and then confirms key major problems. Recommendations for improvement have been suggested, and examples from a real estate enterprise have been taken. On the other hand, the statistical methods, including correlation analysis and variance analysis, are used to analyze safety management issues. The analyses show that the safety management system has been established and favorably implemented under the safety management assessment indicator system represented in this paper.

The indicators in the assessment system that have the crucial impact on the safety management system are the "safety mechanism and guarantee", the "emergency plan and system", and the "safety goals and plans". The "implementation of safety responsibility", "safety education and training", the "job behavior of the decision-making level", and the "job behavior of the grassroots level" have larger effects on safety management behavior than the other indicators. The lower-order indicators that have a major impact on the safety management state are "responsibility fulfilment", "dangerous operations management", "decoration management" (property projects), and "fire control management" (projects under construction and property projects).

Therefore, enforcing the implementation of the main aforementioned indicators is beneficial for improving real estate owners' safety performance. With regard to the main indicators, this paper summarizes practical work and extracts effective experience and safety production management measures in 8 regions (Tables 15-17).

It is significant to note that this study proposes the aforementioned main indicators based on the scores of the first-level indicators and the corresponding second-level indicators, without involving the weights of the indicators. Consequently, the determination of the main indicators is unaffected by the indicators' weight, and the owner can treat them as the primary contents of safety management work.

4.2 Limitations and Directions for Future Research

The safety management assessment indicator system was developed through theoretical development and cased-based development. It provides a fresh way to think about the owner's safety assessment. However, due to the constraints of reality, there are still certain limitations that must be addressed.

- In this research, the establishment and perfection of owner's management system are only from the perspective of safety and the environment. However, an increasing number of enterprises have begun to consider factors of occupational health; thus, further research scope can extend to "safety, occupational health and the environment". The correlation between different management levels and different management issues will also be analyzed using the data collected.
- With regard to different scales (great, medium, small), development stages (initial stage, growth stages, ripeness stage), or types of owners (residential building, commercial building), the intensity and emphases of safety management work are distinct, just like the effects of the diverse indicators on safety performance. Consequently, the assessment indicators' weights should be discussed for the different conditions of owners.
- At present, Chinese construction projects frequently adopt qualitative assessment methods that depend on the abilities of staff. Despite realizing quantification in part through elaborate assessment details (fourth-level indicators), this safety assessment system lacks quantitative methods. Further research on quantitative analysis is essential for future improvements.

Currently, there are limited safety assessment systems for owners and comparative safety management data. Therefore, establishing a database based on practice is indispensable for evaluating the assessment effect and comparing the safety management levels of different owners. More effective measures for owners' safety management will be proposed in future research because of the database.

5. Conclusions

In this study, a safety management assessment model of real estate owners is established based on the relationships among the safety management system, safety management behavior and the safety management state. The safety management system determines safety management behavior, which includes job behavior and organizational behavior which promotes job behavior. Safety management behavior determines the safety management state, which directly reflects the effect of the implementation of safety management behavior and indirectly reflects the degree of perfection of the safety management system. Safety management behavior and the safety management state both determine safety performance.

Most of enterprises have their own safety management system that based on OHSAS 18001-2007. Safety management behavior is the implementation of safety management system. Safety management state is the results of two former elements' joint action.

In this manuscript, safety management system and safety management behavior are universal generally in every industry. There are no obvious differences in diverse industries. Thus, the indicators of them have strong applicability in most industries. Conversely, the indicators of safety management state have great differences in each industry that has different hazards of the person, object and environment. Thus, changing the content of indicators of safety management state can evaluate other industries.

According to the safety management assessment model, a safety management assessment indicator system is established. This assessment system synthetically considers the organizational and individual factors that influence safety performance. This theory enables the safety management assessment to have more comprehensive standards. The four-year practical application demonstrates the applicability and availability of the safety management assessment system in real estate projects. Meanwhile, effective approaches for enhancing owners' safety performance are obtained. Theoretical contributions of this study include the following:

- The three elements that play important roles in safety management assessment are identified, i.e., the safety management system, safety management behavior and the safety management state. The relationships among the three elements that interact with each other and together have an impact on safety performance are clarified.

- The owners' safety management assessment indicator system in this research can also be used as the basic indicator system to evaluate the safety management level of other industries.

Specific practical implications of this study in the real estate enterprises include the following:

- The indicators that play a main role in improving the safety management system are the "safety mechanisms and guarantee", the "emergency plan and system" and the "safety goals and plans". Consequently, to improve the safety management levels, enterprises should focus on enhancing the safety mechanisms and guarantee, perfecting the emergency plan and system, and clearly defining the safety goals and plans.
- To improve safety management behavior, the implementation of safety responsibility, safety education and training, the job behavior of the decision-making level, and the job behavior of the grassroots level are the key points that should be paid more attention to.
- The "responsibility fulfilment of the supervisory departments", "dangerous operations management", "decoration management" (property projects), and "fire control management" (projects under construction and property projects) are the indicators that have the main effect on the safety management state. Therefore, the safety management state can effectively be improved by preferentially improving the management of these facets.

This paper presents a more profound understanding of safety management assessment, in which the safety management assessment model and the indicator system can be used effectively. To improve safety management level of enterprises, the specific theoretical and practical implications will lead researchers and practitioners to pay more attention to safety management assessment. The conclusions can serve as references for both theories and practices related to the safety management assessment of different industries.

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