Construction of risk evaluation index system of housing construction project based on PSR theory

CHENG Lian-hua1, ZHANG Yan-hua1, WANG Zi-yue1
1College of Safety Science and Engineering, Xi'an University of Science And Technology, Xi'an 710054, China

Abstract: In order to enhance the comprehensiveness and rationality of the construction risk assessment index system construction project, this paper divides the risk assessment unit according to the risk composition and risk characteristics of the accidents during the construction of the housing construction project, combined with the actual situation on site. Through the analysis of accident cases, relevant norms and standards, and the analysis of domestic and foreign literatures, the risk factors affecting the construction safety level of housing construction projects are extracted. At the same time, the theory of PSR is introduced to broaden the research scope of engineering construction risk assessment, and the construction model suitable for the construction process evaluation model of housing construction project is proposed. Based on the causal relationship of various risk factors, a systematic and scientific safety evaluation index system is constructed.

1. Introduction

It is the precondition of scientific safety management to clarify the factors influencing the safety level and to further construct an evaluation index system suitable in the construction process of housing projects. Domestic and foreign scholars have carried out many researches on the safety evaluation system in the construction field to make the evaluation index system more comprehensive and objective reflection of the safety level in the construction process of housing construction. Wang Genxia[1] took the construction site as the research object, and constructed the safety evaluation index system of the construction site based on the questionnaire survey and factor analysis method; Yang Haotian[2], Zhang Tianqi[3], Zheng Chaixin[4] summarized the human factors, material factors, environmental factors and management factors to construct the safety index system for high-rise building construction. According to the above research, most scholars tend to construct an indicator system from the four aspects of the internal factors, such as human, machine, environmental and management. The method of dividing and identifying risk factors is a little single, and the identification of external factors (government, social public) of the system needs to be improved. At the same time, most of the current risk assessment focuses on the exploration of evaluation methods. In the aspect of risk identification, the research of basic theory needs to be further improved[5, 6].

In view of this, the author combines the current research on the safety evaluation of building construction, from the system point of view, analyzes the system composition of the construction site. Through the in-depth study of accident cases, normative standards, and domestic and foreign literatures, the pressure P - state S - response R is taken as the main line, considering the correlation, dynamics and conductivity between risk factors. Comprehensive analysis and combing the risk factors affecting the construction safety of housing construction. The risk evaluation index system is constructed to provide theoretical support for the construction safety management of housing construction projects.
2. System composition analysis of construction site

From the point of view of system engineering, construction engineering is a complex open system \cite{7}. There are many uncertainties and various risk factors in the construction process. At the same time, the construction process is disturbed and influenced by many factors outside the system. In order to facilitate analysis, this paper first divides the construction site of housing construction project into three parts according to the actual situation of the project.

(1) Auxiliary Production area

Auxiliary production area refers to the area that provides preparations for the implementation of housing construction projects, mainly including steel processing shed, woodworking processing shed, material stacking area, etc. The steel bar and woodworking processing shed have the characteristics of high labor intensity and high mechanization. At the same time, its production mode is mainly based on manual operation and mechanical equipment cooperation, which is prone to mechanical injury accidents. Material stacking area mainly stores raw materials, steel, timber, formwork and other materials, which are prone to fire accidents for flammable and explosive materials.

(2) Construction work area

Construction work area is an important site for housing construction projects. Because of the complexity of structural engineering and the characteristics of various construction processes, accidents are more likely to occur than other areas. During the construction process, accidents that occur frequently include falling, collapsing, object strikes, vehicle injuries, etc., which are likely to cause huge casualties and economic losses. Therefore, the construction of foundation and main body has become the stage with the largest workload and the broadest problems involved in the construction of engineering projects.

(3) Personnel-intensive area

Personnel-intensive area includes office area, staff dormitory buildings, canteens and so on. The most frequent accidents in this area are fires. Fires in personnel-intensive areas are characterized by many combustible materials, rapid fire spread, many electrical equipment, high concentration of people and difficulty in evacuation. Once a fire accident occurs, it is often accompanied by crowded trampling, panic evacuation, mass incidents and other comprehensive safety, which can easily cause tragic economic losses and casualties.

Based on the above analysis, this paper divides the construction site of the housing construction project into three parts: auxiliary production area, construction operation area and personnel-intensive area as the evaluation unit. The specific risk evaluation unit is shown in figure 1.

![Risk assessment unit](image-url)
3. Determining method of index system

Based on the classification of construction risk assessment units of housing construction projects, the risk indicators of each evaluation unit are obtained initially. Combining with the actual situation of the site, the theory of PSR ("pressure-state-response") is introduced to construct a systematic and scientific safety evaluation index system.

3.1 Primary selection of indicators

In view of the limitation of the length of the article, this paper takes the construction work area as an example, where there are many kinds of dangerous sources and the problem of leakage is relatively complex. Firstly, referring to the relevant standards and norms of Classification Standards for Occupational Casualty Accidents in Enterprises GB6441-1986, Classification and Code for Hazardous and Hazardous Factors in Production Process GB/T13861-1992, Code for Design of Construction Organization GB/T50502-2009, and considering the actual situation of housing construction, this paper collects about 40 cases of housing construction accidents in recent 13 years from 2005 to 2017, and analyses the causes of high accidents. Direct and indirect causes of accidents such as falling, object striking, collapse, lifting injury, collapse, mechanical injury, electric shock. Secondly, by consulting domestic and foreign literature, the risk factors affecting the construction safety of housing construction projects summarized by many scholars are analyzed and refined.

After the above analysis and combing of the causes of accidents, it is found that there are many duplicates in the basic factors of each accident. These factors can be classified into four categories: human factors, material factors, environmental factors and management factors. Therefore, starting from these four categories, this paper obtains a statistical table of risk factors in the construction process of housing projects, such as Table 1.

| Index            | Risk factors                                                                 |
|------------------|-----------------------------------------------------------------------------|
| Human factors    | Personnel misoperation, violation of regulations, improper position, irregular or missing use of labor protection equipment, absence of valid certificates, low technical level, low educational level, poor physical fitness, psychological abnormality and abnormal identification function, etc. |
| Material factors | Improper selection of construction machinery and equipment, inappropriate protection of transmission parts of equipment, non-standard wiring of electrical equipment, no leakage protector of equipment, failure of equipment safety device, defective accessories, abnormal operation of equipment, etc. |
| Environmental factors | Uneven foundation, poor working environment, poor meteorological conditions, unclear underground pipelines, inappropriate layout of general plan and functional zones, narrow workplaces, cross-operation, unsafe traffic line configuration, etc. |
| Management factors | Chaotic management, inadequate supervision, inadequate responsibility system for production safety, imperfect management system for production safety, inadequate training and education system, imperfect rate of rules and regulations, inadequate safety costs, lack of qualifications for post practice, etc. |

3.2 PSR "pressure-state-response" model

3.2.1 Basic theory of PSR model

The PSR conceptual model was put forward by the Organization for Economic Cooperation and Development (OECD) and the United Nations Environment Programme (UNEP) in the late 1980s. The model was initially used for the study of environmental indicators. The thinking logic of the PSR theory is that human practice exerts certain pressure on the system "P", which leads to a benign or malignant change in the system state "S". When the system has a malignant change, the system responds to the malignant change "R". In order to restore the degradation of system security attributes
or other attributes, when there is a benign change in the system, the system will respond to maintain and enhance the system security attributes or improve other attributes, and the entire system has dynamic conduction characteristics, forming a dynamic cycle mode.

At present, the PSR framework model analysis method has become a standard method for identifying the environmental impact of planning and establishing an evaluation index system in China. It is used to express the interaction between human beings and the environment and to study the environmental problems of the framework system [10,11]. It is suitable for evaluating the dynamic and changing attributes of complex systems [12]. The process of housing construction involves multi-type, multi-process and multi-personnel cross-operation, which is often affected by complex, changeable and uncontrollable factors. With the development of the project progress, the workplace and work content are changing, and the subjective and objective factors facing each stage are also changing, which belongs to a dynamic system. Therefore, the application of PSR theory in the process of housing construction can highlight the causal relationship between pressure, state and response, avoid the redundancy of selecting risk factors, reflect the safety problems faced in the process of housing construction in a differentiated and comprehensive way, and rely on its dynamic transmission characteristics, so that the housing construction system can be continuously improved.

3.2.2 Analysis of the influencing factors of housing construction risk based on PSR theory

This paper introduces the PSR theoretical model. According to the logical relationship and characteristics of the model, when constructing the safety evaluation index system of housing construction operation area, the following index framework structure is considered: human, physical and environmental activities exert certain pressure on the system safety of construction operation area. Certain pressures, which lead to various adverse risk factors during the construction process, and then the evaluation unit shows the corresponding safety status due to the pressure, in order to relieve the pressure and the state changes with the pressure, government or management departmental policies and management regulations, as well as responding to these changes through changes in consciousness and behavior [11]. For example, the weak safety awareness and low education level of the operators lead to the poor risk identification ability, the weak emergency safety awareness, which are the incentives for the accidents and exert certain pressure on the system safety of the construction operation area. Under the influence of these pressures, the occurrence rate of three violations of the construction site operators is caused. Management departments respond from safety education and training, safety regulations and other aspects to alleviate the state changes caused by pressure. At the same time, the process of "pressure", "state" and "response" of each evaluation unit will continuously improve the safety level of building construction system. Although the causality or logical state of the above indicators is not one-to-one correspondence, they are related to each other and have synergistic effects. In summary, the model framework for evaluating the safety level of the construction work area is shown in figure 2.

From the above figure, it can be seen that according to PSR (Pressure-State-Response) model, the safety situation of construction area is analyzed. According to the framework of figure 2, the "operators", "facilities and equipment" and "the environment inside and outside the system" are classified as the pressure index P; "site safety state" is classified as the state index S; "management" is classified as the response index R.
4. Construction of construction risk evaluation index system for housing projects

Based on the division of risk assessment units and the primary selection of indicators for housing construction, according to the overall design of PSR model and combined with the characteristics of PSR model, the possible risk factors in the construction process of construction operation area are comprehensively analyzed and screened. The overall safety level of the area is regarded as the target layer; "operators", "facilities and equipment", "internal (external) environment of the system" and "management" are taken as first-level indicators. Through the accident case, relevant normative standards and analysis of domestic and foreign literatures, the safety secondary evaluation index of the construction operation area is obtained. As shown in table 2 below, the evaluation index system consists of one target layer, five first-level indicators and fifteen second-level indicators.

The specific identification results are as follows:

(1) From the aspect of pressure, a total of three first-level indicators of operators, facilities and equipment, and system (inside) and external environment are identified. 6 secondary indicators of safety awareness, education level, construction equipment/equipment failure, natural environment, working conditions and social conditions are identified. Safety awareness reflects the sense of responsibility of the operators and the ability to identify potential safety hazards, their own awareness of emergency safety, and the awareness of monitoring and alerting others to safety. The level of education reflects the knowledge level of the workers on construction technology, safety production, safety management, etc., including the skilled operation capabilities of tower cranes, cranes, transport vehicles, etc., scaffolding, formwork, basket installation and disassembly skills. Construction equipment/equipment failures include equipment failures such as tower cranes, cranes, transportation vehicles, construction elevators, material hoists, which have a direct impact on construction progress and construction safety. The natural environment includes natural factors such as heavy precipitation, heavy snowfall, and climatic temperatures that affect construction safety. The working conditions refer to the impact of the narrow construction site, the mess of the work site, the cross-operation, the layout...
of the engineering function partition and the safety distance. Social conditions refer to the government and public. The government supervises the establishment of the safety production supervision and management system of construction enterprises, the daily operation, the post-accident treatment, the implementation of rules and regulations, and the public public through reporting.

(2) From the aspect of status, a total of one level indicator of the occurrence of the field safety status is identified. There are five secondary indicators: the incidence rate of three violations, the pre-job safety training rate, the safety and reliability of facilities and equipment, and the comfort level of the working environment. The incidence of the three violations refers to the violation of the rules and regulations, the illegal operation, and the violation of the command. Accepting the pre-job safety training rate refers to the compulsory safety training for newly hired temporary workers, contract workers, laborers, rotation workers, and contract workers. The rate of guarding equipment refers to the setting of the protective equipment on the edge of the construction site, the opening of the hole, and large machinery. The safe and reliable condition of facilities and equipment indicates the integrity rate of mechanical equipment, the safety inspection of special equipment, and the coverage of protective equipment. The comfort level of the working environment refers to the suitability of construction site lighting, noise, weather temperature and humidity, and the rationality of the working space.

(3) From the aspect of response, a total of one level indicator is identified. 4 secondary indicators of safety rules and regulations, safety education and training, safety investment, and emergency management are identified. The establishment of safety rules and regulations is the fundamental guarantee for the safe construction of construction areas. Safety education and training can enhance the safety awareness and self-protection ability, safety knowledge and operational skills. Reasonable safety investment and emergency management capabilities can reduce accidents and reduce the severity of accidents.

Table 2. Safety assessment index system for construction operation area

| target layer          | theory                  | first-level indicators            | second-level indicators                  |
|-----------------------|-------------------------|-----------------------------------|------------------------------------------|
| P pressure            |                         | Operators                         | Safety consciousness, educational level  |
|                       |                         | Facilities and equipment          | Construction equipment, equipment failure|
| In-system (outside)   |                         | Environment                       | Natural environment, Working conditions   |
| Social condition      |                         |                                   |                                          |
| Construction work area| S state                 | Site safety status                | Third violation rate, Accept pre-job     |
| safety level          |                         |                                   | safety training rate, Guarding equipment  |
|                       |                         |                                   | ratio                                    |
|                       |                         |                                   | Safety and reliability of facilities and equipment, The comfort level of the working environment |
| R response            | management              |                                   | Safety regulations, Safety education training, Safety investment, Emergency management |
5. Conclusion
(1) Based on the in-depth study and analysis of PSR theoretical model in the field of construction, the construction model of PSR theoretical model is put forward. Four methods are used to summarize the risk factors of "pressure-state-response", and a safety evaluation index system including one target layer, five secondary indicators and 15 tertiary indicators is constructed, which is a risk index system for housing construction. The construction provides theoretical support and new ideas.

(2) Based on the established risk evaluation index system of housing construction project construction, combined with the actual situation of the site, and using the dynamic cycle characteristics of PSR theoretical model, we can move forward the weak links, promote the combination of static management and dynamic management of enterprises and management departments, and control the risk level in an acceptable range.

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