

Application of Griddization Management to Construction Hazard Management

Lingzhi Li, Jiankun Zhang, Tiantian Gu

Abstract—Hazard management that can prevent fatal accidents and property losses is a fundamental process during the buildings' construction stage. However, due to lack of safety supervision resources and operational pressures, the conduction of hazard management is poor and ineffective in China. In order to improve the quality of construction safety management, it is critical to explore the use of information technologies to ensure that the process of hazard management is efficient and effective. After exploring the existing problems of construction hazard management in China, this paper develops the griddization management model for construction hazard management. First, following the knowledge grid infrastructure, the griddization computing infrastructure for construction hazards management is designed which includes five layers: resource entity layer, information management layer, task management layer, knowledge transformation layer and application layer. This infrastructure will be as the technical support for realizing grid management. Second, this study divides the construction hazards into grids through city level, district level and construction site level according to grid principles. Last, a griddization management process including hazard identification, assessment and control is developed. Meanwhile, all stakeholders of construction safety management, such as owners, contractors, supervision organizations and government departments, should take the corresponding responsibilities in this process. Finally, a case study based on actual construction hazard identification, assessment and control is used to validate the effectiveness and efficiency of the proposed griddization management model. The advantage of this designed model is to realize information sharing and cooperative management between various safety management departments.

Keywords—Construction hazard, grid management, griddization computing, process.

I. INTRODUCTION

IN recent years, with the development of social economy in China, the construction industry plays an important role in promoting China's whole economy. However, construction industry is one of the most hazardous industries [1] and the safety record of construction industry in China has always been poor. Various construction accidents take place endlessly, which harasses the whole building industry and damages to construction workers. It is well known that the effective way to avoid construction accidents is by eliminating or reducing hazards during the construction operation [1]. However, in China the performance of construction hazard management is

poor, which because there is lack of supervision resource as well as the traditional and ineffective management methods. Therefore, it is urgent to develop an effective and efficiency management method for construction hazards.

According to [1], hazards refer to the source of dangers, which are the potential unsafe factors that can cause injuries or property losses. And the Occupation Health and Safety Assessment Series for health and safety management systems (OHSAS 18001) also defined hazard as any situation, substance, activity, event, or environment that could potentially cause injury or ill health [2]. In China, the Occupational Health and Safety Management System Specification defined that hazard is the root or activity that could potentially cause injury, illness, property loss, or environment damage. All these definitions illustrated that hazard is the source of damage and the essential of hazard is the unexpected energy which can cause damage. Specifically, once the unexpected energy released, it would result in damage. Hence, in the construction sites, hazard is the energy or energy carrier that exists in construction process.

The application of information technologies to construction safety management is the demand of current information society, which can also enhance the work efficiency. In 2004, the Ministry of Construction in China, who takes the overall responsibility in managing the construction industry [3] proposed the strategy of information development. For that, this paper explores the griddization management method to ensure the process of hazard management is effective and efficiency.

II. DEFINITIONS

A. Construction Hazard

Since 1970s, the definition of hazard is described clearly in the international scope. According to "*Identification of major hazard installations*" (GB18218-2000), a hazardous installation is defined as an installation that produces, processes, handles, uses, disposes of or stores, either permanently or temporarily, one or more hazardous substances or categories of hazardous substances or substances in quantities which exceed prescribed amounts. However, there is no standardized definition for construction hazards in China. The governmental safety management organizations in different regions listed different definitions for construction hazard. In 2006, Hebei province announced that construction hazards are the branch sub-item projects which can result in construction safety accidents. Similarly, Nanjing province believed that construction hazards are the branch sub-item projects that have potential safety problems. Specifically, there are two crucial concepts about the definition of construction hazard. First, all

Lingzhi Li is with the Department of civil engineering, Southeast University, Nanjing, Jiangsu 200196 China. (phone: 86-15295529630; e-mail: lingzhiseu@hotmail.com).

Jiankun Zhang is with Department of civil engineering, Southeast University, Nanjing, Jiangsu 200196 China. (e-mail: zhang_jk@vip.163.com).

Tiantian Gu is with the Department of civil engineering, Southeast University, Nanjing, Jiangsu 200196 China.

construction hazards can cause major safety accidents in construction sites. Second, these construction hazards exist in branch sub-item projects. On basis of the different definitions in different regions, this paper concluded that in the construction process, all hazardous facilities and sub-work processes that can cause major safety accidents are defined construction hazards.

Besides, once in certain situations, construction hazards can cause accidents. This paper defined these certain situations as trigger factors. Deng [4] and Li [5] proposed that trigger factors

come from the second hazards which are peoples' unsafe behavior, management problems and environment factors. Based on that, this paper illustrated that the trigger factors of construction hazards are peoples' behavior, status of materials and machines, environment factors and safety management. Although construction hazards exist in construction sites, if without trigger factors, all these hazards cannot cause safety accidents (Fig. 1). Hence, analyzing trigger factors for construction hazards are important.

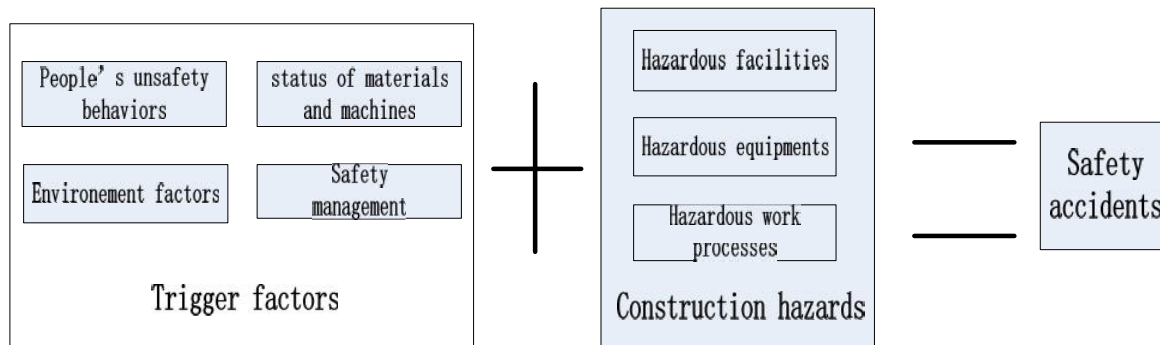


Fig. 1 Mechanism of trigger factors

B. Griddization Management

Recently, "griddization management" is most frequently applied in city management. In 2005, griddization city management was performed in the East district of Beijing. The performance of this application is effective which can meet the requirements of modern metropolitan and achieve high efficiency management. Griddization management in city management mainly refers to dividing the city areas into grid units and assigning these grid units to professional staff who will be responsible for the management of assigned units [6]. The gridding urban management considers the grid units as the carriers and integrates data resources, information resources, management resources and service resources to realize the resource sharing and smart management.

There is no standardized concept for griddization management. The frequently cited definition is proposed by [7] which illustrated that griddization management applies the grid technology, divides the objectives into grid units, realize the information share between grid units and achieve the resource integration and high efficiency. This application can supply much more powerful information dealing capability than single computer to promote information amalgamation and share.

For the application of griddization management in construction hazards, this paper concluded two points: first, with grid technology, this model should divide the management objects into grid units, integrate resources, adjust the organization structure to achieve full sharing of resources and improve the efficiency of management; second, this model would gather, update and schedule resources and information, break the information island and assign management tasks to realize the real time supervision of construction engineering

major hazards status and the construction hazards management with high efficiency and low cost.

III. DEVELOPMENT OF GRIDDIZATION MANAGEMENT MODEL FOR CONSTRUCTION HAZARD

A. Grid Architecture

Grid architecture is about how to build the grid infrastructure, which describes the basic composition and function of the grid, and depicts the mechanism of grid operation [8]. In this paper, the grid architecture was created based on knowledge grid and regarded construction hazards as management objectives. Stakeholders required a lot of knowledge resources and services when performing administrative work [9], and all resource scheduling are finished automatically by the knowledge grid architecture. Therefore, the griddization architecture for construction hazards management was designed which includes five layers: resource entity layer, information management layer, task management layer, knowledge transformation layer and application layer, as shown in Fig. 2.

According to Fig. 2, the application layer includes grid users, visualization services, algorithm services, knowledge representation and identity authentication [10]. In knowledge transformation layer, knowledge base, transformation service, knowledge release and authorization management are the main function parts. This layer plays a role of bridge in grid architecture which unifies semantic definition for different types of knowledge, blocks the heterogeneity and distribution characteristics, and provides a unified interface for each layer through the grid middleware technology for distributed organization. Besides, task management layer is designed

separately in this paper, in which major tasks in the process of hazard management are submitted to this layer, and the grid infrastructure on the allocation of tasks to complete the task in the management, implementation and monitoring [10]. Information management layer is considered as a resource management in this grid architecture. Resource entity layer a

variety of heterogeneous database [11], hardware platform, information collection device, network communications equipment, computers and other hardware and software resources, to achieve the construction of major hazard installation grid management to provide technical support.

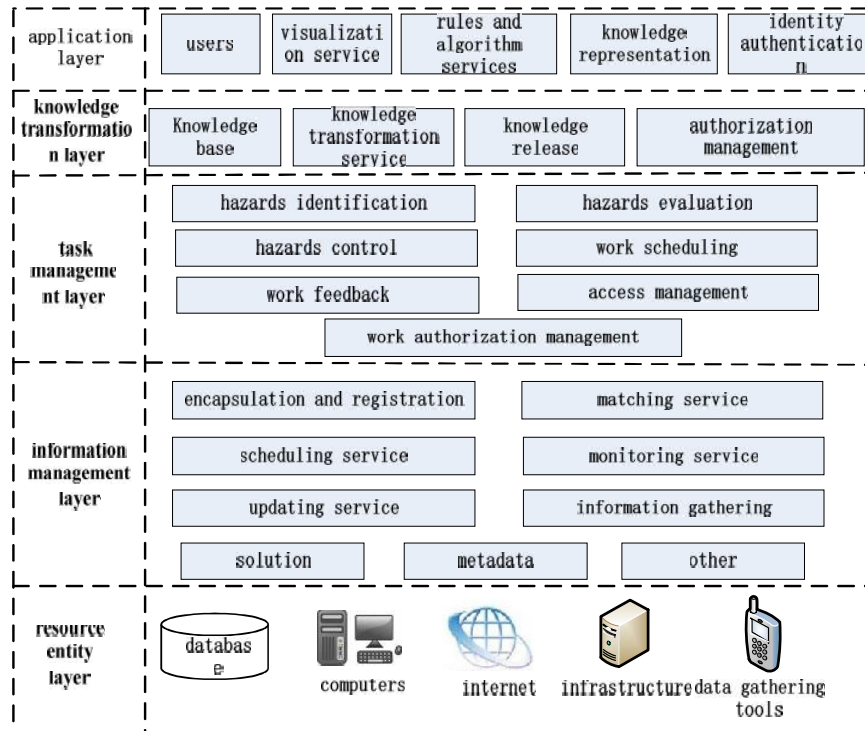


Fig. 2 Grid architecture for management of construction hazards

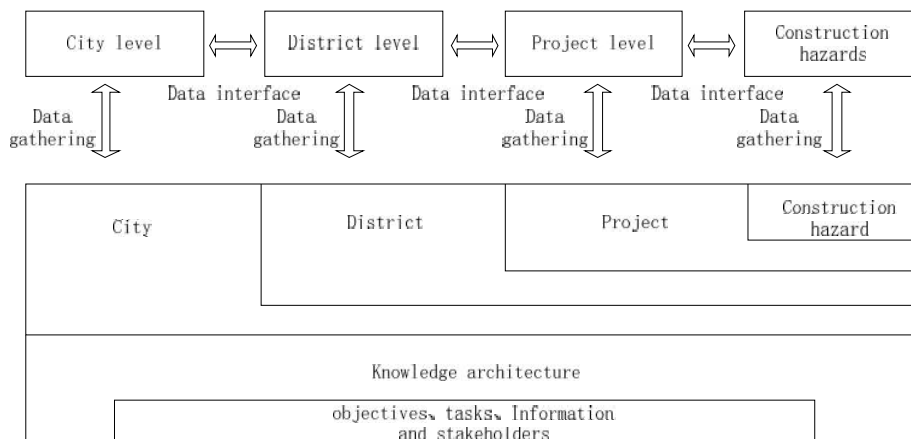


Fig. 3 Griddization management model for construction hazard

B. Griddization Management Model for Construction Hazard

On basis of the architecture in Fig. 2, this paper designed the griddization management model from three levels: city level, district level and construction site level. As shown in Fig. 3, these three levels exist interface between each other, which can

achieve rapid transfer and sharing of information. The construction of this model is based on the grid technology in the management concept of "regional segmentation, task coordination" [12]. Task is clearly divided, clear information input, output, direction, and jointly build upon the construction

of major hazards grid architecture, can better realize information integration and collaborative management tasks.

The idea of griddization management model is to assign the processes of the identification, evaluation and control for major hazards management to the responsible units, including the construction units, construction units, supervision units and institutions of the third-party evaluation, each unit directly through a user interface management system sends a message to the grid, and accept the grid management system of instructions, complete the task, and as a regulator of construction production safety supervision and administration department is responsible for monitoring information, task execution, monitoring and verification of implementation effect, and through the different levels of grid management system to realize information sharing [13].

IV. CASE STUDY

Once the griddization management model was created, this paper used a case study to verify this mode. Project A in Nanjing city was analyzed. Based on the basic model, a griddization management system with three levels was designed for this case shown in Fig. 4.

The city level in griddization management system is the whole construction of major hazards management center, have operation permissions users is nanjing construction production safety surveillance. Now the site has four first-line supervision departments, each department has its own regulatory regions, respectively is: supervision subject (Jianye district, Gulou district), the second section (Xuanwu district, Qixia district),

supervision and sorted (Baixia district), supervision (Qinhuai district, Xiaguan district), four families. In the city grid management system, each department has its own user login interface, is responsible for the area of construction within the supervision and management of major hazard installation, review the information, instructions, etc. Moreover, setting a webmaster or general user login interface, is responsible for supervision and administration of the construction in the city major hazards, and to test the safe management of each department. The project belongs to the Jianye district, within the scope of supervision and the management of the subject.

District level in this griddization management system contains the operation of the user all the division of housing and construction bureau, within the scope of its main responsibility is the area and to put on record in the project construction supervision and management of major hazard installation work, mainly responsible for grid management in the process of reviewing information and related instructions, etc.

In the Project level of the griddization management system, the operation users are many, mainly include the construction units, supervision units, construction units, institutions of the third-party evaluation, so each user login interface are different, can only view and edit its responsibilities.

Specifically, this paper selected a construction hazard in Project A as the example to perform griddization management. After management and evaluation, the final control solutions for this hazard is listed in Table I.

TABLE I
CONTROL SOLUTIONS FOR BEAMS FORMS IN PROJECT A

No.	Individual Level	The specific content of the scheme	executable unit
1	qualified	More than 70% skilled construction personnel should be equipped and their skill training should be strengthened	contractor
2	disqualified	The three level safety education must be covered and security managers should be completed	Construction investment party& contractor
3	qualified	Replace the steel pipe which does not meet the requirements of wall thickness and reuse it after testing its performance	contractor
4	qualified	Safety management personnel conducted on site supervision of the installation and removal of large mechanical equipment in strict accordance with the specification	contractor
5 ₇	qualified	Check the temporary electricity utilization of the mechanical equipment. If the temporary electricity utilization is not normal, it should be handled in a timely manner	contractor
6	qualified	Do a good job in site management to provide good working conditions	contractor
7	disqualified	Set the base drainage facilities	contractor
8	disqualified	Set the bottom of the pole base	contractor
9	disqualified	Accordance with the provisions set vertical and horizontal sweep shot	contractor
10	qualified	Complete the major hazard management system of construction	contractor
11	disqualified	Complete with security managers and clear the division of labor	Construction investment party& contractor
12	disqualified	The safety education must be covered and the safety awareness of construction workers must be strengthen	Construction investment party& contractor
13	disqualified	Taking care of the confiding technical intentions and recording	Construction investment party& contractor

V. CONCLUSION

With the development of the economy, the construction industry also welcomes the golden age. In the meantime, the number of safety accident and the death toll of construction Projects in China have been high. So the safety situation of our construction is quite tough and we must take some measures to improve the level of safety management. As we all knew, Dangerous sources are the root causes of construction safety

accidents, while the major hazard is more likely to cause accidents. This paper focuses on the hazards in the construction process. Taking full advantage of the current information technology and its method for implement, such as grid computing technology and the concept of grid-based management, to design the griddization management model of construction hazard for the purpose of improving the efficiency of management.

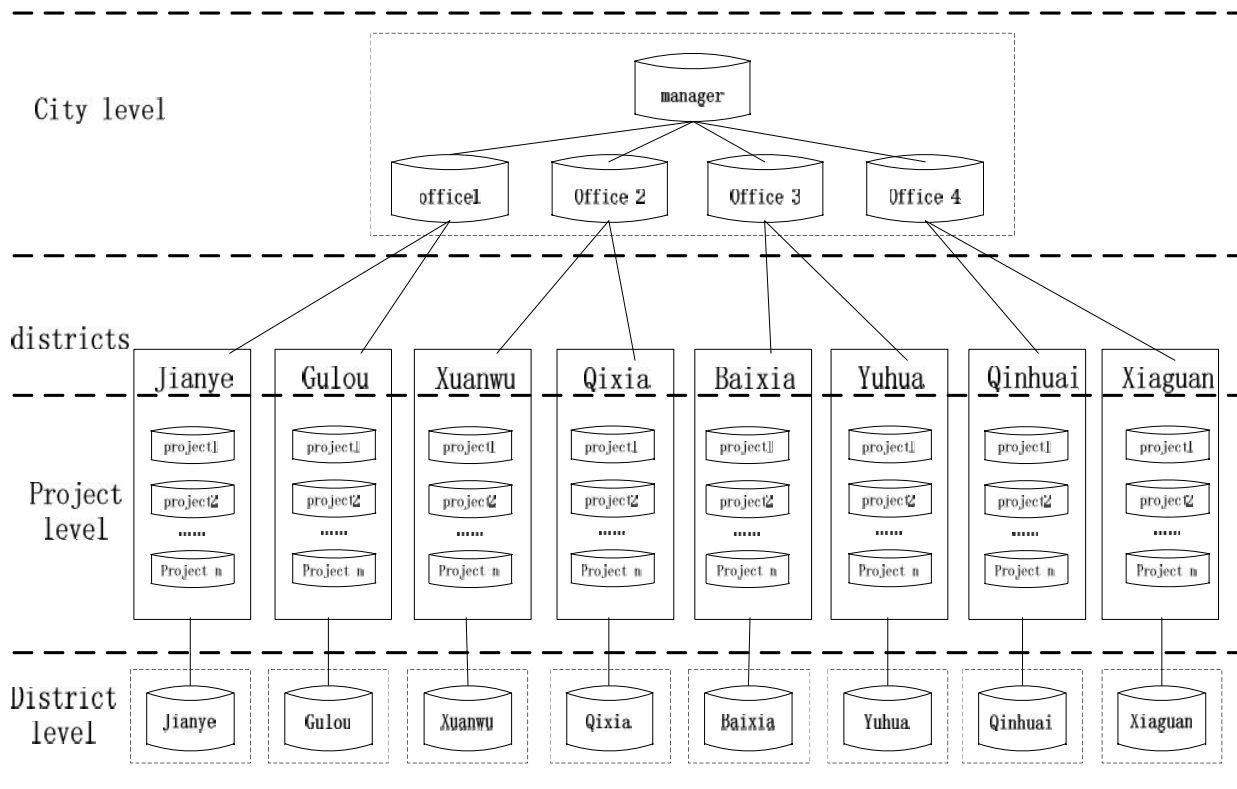


Fig. 4 Griddization management model in Nanjing City

First, the definitions of construction hazard as well as the griddization management are developed in this paper, which form the backbone of griddization application in construction management. Second, the grid architecture with five layers is created for construction hazards management based on the knowledge grid infrastructure. These five layers include resource entity layer, information management layer, task management layer, knowledge transformation layer and application layer. All resources and information flows are performed in this grid architecture. Third, according to the grid principles, this paper coded all construction hazards through dividing them into city level, district level and construction site level. In this way, all construction hazards are divided into grids. Importantly, the griddization management process of construction hazard, including hazard identification, assessment and control, is performed also in the layer of task management in this grid architecture. Finally, this paper takes a construction site in Nanjing as one example to verify the performance of the proposed griddization management model. Thirteen construction hazards are evaluated and all solutions are proposed in this case study. On basis of the griddization advantages, this paper concluded that with this griddization management model, all construction stakeholders could enjoy information sharing and cooperation, which will save management resources and enhance the effectiveness of safety management.

ACKNOWLEDGMENT

Authors would like to express their appreciate to all Delphi experts and reviewers of the paper, and to the National Planning Office of Philosophy and Social Science, P.R.C. (14AJY013), and the Fundamental Research Funds for the Central Universities and the Central Universities and graduates' Science and Innovation Foundation of Jiangsu Province (KYLX_0208) for financial support.

REFERENCES

- [1] Hammer, W., *Handbook of System and Product Safety*, Prentice Hall Inc, 1972.
- [2] OHSAS. OHSAS 18001:2007 (Occupational Health and Safety Assessment series), 2007.
- [3] Tam, C. M., Zeng S.X., Deng Z.M., "Identifying elements of poor construction safety management in China." *Safety Sci.*, vol. 42, no. 7, pp.569-586, 2004.
- [4] Deng, X., *Study and Application on Dynamic Management System of Major Hazard of the Construction Site*. Chongqing: Chongqing University, 2009.
- [5] Li, H., *Research on the safety evaluation of construction site based on hazard management*. Beijing: Beijing China University of Mining and Technology, 2011.
- [6] Chen, P., *Gridding urban management model*. Beijing: Beijing University Press, 2006.
- [7] Zheng, S., Xu, H., Wang, H.C. (2005). "A survey of grid and grid management," *Syst. Eng.*, vol.23, no.3, pp.1-7, 2005.
- [8] Xia, H. and Chen, G., "Review of knowledge grid literature," *J. Intell.* vol. 26, no. 6, pp.869-876, 2007.
- [9] Harper, R. S. and Koehn E., (1998). "Managing industrial construction safety in southeast Texas." *J.Constr.Eng.M.*, vol.124, no.6, pp. 452-457, 1998.

- [10] Ebohon, O. J., Haupt, T. C., Smallwood, J. J., Rwelamila, P. D. "Enforcing health and safety measures in the construction industry: command and control versus economic and other policy instruments," in *Proc. 99th CIB Working Commission*, Florida, 1999.
- [11] Gunningham, N., "Towards innovative occupational health and safety regulation," *J. Ind. Relat.*, vol.40, no.2, pp.204-231, 1998.
- [12] Gambatese, J. A., *Designing for safety: construction safety and health management*. New Jersey: Prentie Hall, 2000.
- [13] Blair E H., "Achieving a total safety paradigm through authentic caring and quality," *Prof. Safety.*, vol.41, no.5, pp.24-27,1996.

Lingzhi Li is a Ph.D candidate in the Department of Construction Management and Real Estate, Southeast University. And now she was a visiting Ph.D candidate in the School of Building Construction, Georgia Institute of Technology in 2015. Her research fields include construction safety management and the facility management for public housing and space management for elderly facilities. She is also the member of International Facility Management Association (IFMA).