Research on the Emergency Management Strategies of China High-Speed Railway Based on Risk Network Theory

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Abstract Safe operation and rapid emergency response are taken as preconditions to develop China high-speed railway. From the perspective of a whole life cycle, this paper identifies the key risk factors of China high-speed railway by utilizing the risk network theory and proposes some emergency management strategies accordingly. Early warning and prevention of safety crisis in China high-speed railway emergency management is emphasized particularly. The proposals may help to promote the emergency management capability of China high-speed railway.

Keywords Emergency management • High-speed railway • Risk network • Strategy

1 Introduction

China high-speed railway has some world-class technologies, however, its management, services, especially the emergency response capabilities, cannot keep pace with the rapid technological development. The problems arisen from the "7·23" major accident on Wenyong Line, such as the quality of equipment and personnel, on-site control, indicate that the safety management and emergency response capabilities of China high-speed railway are still far from enough. Social consensus considers that if high-speed railway could be vigorously developed in China, the operational safety and emergency response capabilities should be taken as the preconditions.

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In accordance with the present situation of China's high-speed rail, the scholars mainly carried out two aspects of researches, namely the safety supervision and emergency response of China high-speed railway. As far as safety supervision is involved, the scholars mainly from the perspective of risk management, put forward their solutions to the key risk factors that may interfere with the safety operation of the high-speed railway. Y.Q. Tang (2011), W.Q. Li (2010) and C. Tang (2010) hold that human is the key factor that interferes with the safety operation of the high-speed railway, therefore, they proposed that it is a best choice to strengthen staff training, incentives, assessment and psychological counseling in effectively enhancing the safe operation. F. Wei (Fu 2012) took the public works sector of Zhengzhou-Xi'an high-speed rail as an example, and mainly explained the risk management responsibilities, risk identification and risk control of high-speed railway and proposed relevant solutions; M.J. Cai (2012), J.E. Bao (2012) and H. Li (2012) respectively took quality supervision on the construction site, communication safety management and vehicle service safety management as the key risk factors and proposed relevant solutions.

In emergency response, H.Y. Yan et al. (2012), X.J. Hou (2010), Q.W. Yan (2011) and some others put forward their emergency management plans from a technical point of view according to the most common equipment failures of different CRH trains; Q.X. Guo (2012) made an analysis on the emergency communication system in times of high-speed rail and proposed his plan on the construction and optimization of China railway emergency communication system. From the management perspective, H. Zhao (2011) and L.S. Gu (2011) introduced the advanced management experience concerning high-speed railway in Japan, France and Germany, and provided their valuable advice on the development of China high-speed railway in three aspects, namely, technological innovation, improving legislation and operational management system as well as strengthening the emergency response system construction; H.W. Ai et al. (2008), W.J. Wang et al. (2006), and C. Lu and L.S. Zhou (2008), by building high-speed railway emergency plan procedure models with computer technologies, provided their proposition for the formation of China high-speed railway emergency plan; K.Y. Sun (2012) put forward his suggestions to improve China high-speed railway safety and emergency response capabilities from the view of high-speed railway emergency response decision support systems.

These studies above have provided great help to the improvement of China high-speed railway safety and emergency response capabilities. However, there is still something to be improved in these researches. For example, instead of applying systematic theories as guidance, these researches simply listed part of the problems encountered in work situations concerning the security risk factors identification of China high-speed railway. Although some scholars used the Bayesian network theory to analyze risk factors of large-scale projects, what they did was to analyze some detailed parts of the project instead of analyzing the risk factors of the whole process of the project (Zhou and Peng 2009). As for their researches on China's high-speed railway emergency response, they were limited to the response propositions and response plans for incidents that already occurred rather than

taking the emergency management as a whole process which includes the dynamic process of reduction, readiness, response and recovery. But the limitations bring a lot of enlightenment to this paper.

2 Methodology

The difference from other similar researches is that this paper identifies the key risk factors in China high-speed railway from life cycle perspective by applying the risk network theory which is widely used in large-scale projects. Based on this, puts forward the strategies for China's high-speed rail emergency management and propose some advices to the prevention of potential risks in China high-speed railway.

2.1 Definition of Risk Network

China high-speed railway involves plenty of technology R & D work, precision coordination and management, therefore lots of uncertainty and risks exist. The causes and consequences of risks are not a simple causal relationship, there also involves the interaction and coordination of different relations. If these relationships are expressed, they constitute a network, and this network used for the analysis of the risks is called a risk network.

The risk network for China high-speed railway project can be denoted as:

$$G = (V, E) \tag{1}$$

In this equation, V stands for the set of nodes, E is the set of relations. In this definition, the set of nodes V contains risk information, risk factors, risk events, and risk loss, etc., while the set of relations E indicates linkages between the nodes.

2.2 Risk Network Construction Method for High-Speed Railway

The two steps to construct the risk network of the high-speed railway project are risk identification and network construction. The risk identification of China high-speed railway is done on the basis of discomposing the work structure and risk structure by applying systematic analysis to identify the risk factors. This paper takes the life cycle theory to guide the work structure decomposition of China high-speed railway for the reasons that: firstly, at different stages in the life cycle of the construction

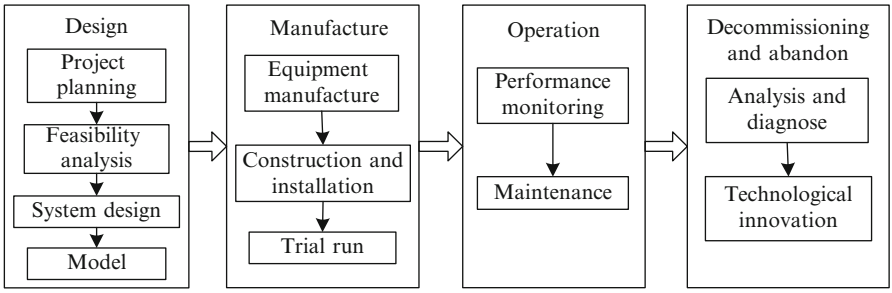

Fig. 1 Whole life cycle of the high-speed railway

project, the construction contents, tasks and resources may differ greatly, therefore the risk factors that influence the construction tasks at different stages of the project may also vary. Secondly, from the overall point of view, in the risk analysis of a construction project all risk factor at different stages are inter-related and are in one time sequence. The whole life cycle of the high-speed railway project in this paper includes the four stages, that is, design, manufacture, operation, decommissioning and abandon, as shown in Fig. 1. Stage "Design" are mainly about project planning, feasibility analysis, system design and model experiment. Stage "Manufacture" are mainly about equipment manufacture, construction and installation and trial run. Stage "Operation" includes performance monitoring and maintenance. Stage "Decommissioning and abandon" includes analysis and diagnose and technological innovation.

In order to accurately identify the risk factors for China high-speed railway and sort out the complex relationship between the risk factors, by organizing the data and documents, this paper first made a list of the risk factors and risk events throughout the life cycle of the high-speed railway. After discussions with experienced experts in the fields of project construction and management, selected the key risk factors directly related to the safety of China high-speed railway and constructed the risk network. Based on this risk network, the strategies for high-speed rail emergency management are proposed.

3 Results

3.1 Risk Network for China High-Speed Railway

There are four phases in the life cycle of China high-speed railway: design, manufacture, operation and decommissioning. There are different tasks in each phases, the risk factors contained in these tasks are interrelated and influence each other, which constitute the risk network of the China high-speed railway.

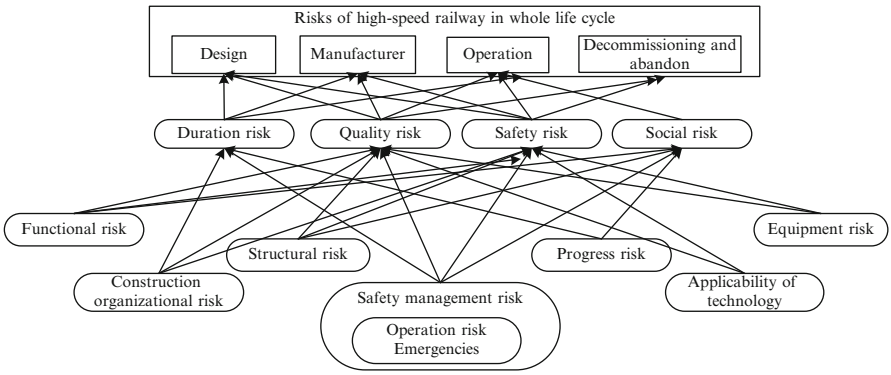

Fig. 2 Risk network of China high-speed railway

Figure 2 indicates that there are four major risks in the whole life cycle of China high-speed railway, which are duration risk, quality risk, safety risk and social risk. These risks are caused by some basic risks, such as function risk, structural risk, progress risk, equipment risk, construction organization risk, safety management risk for operation and emergencies, and applicability of technological, etc.

Meanwhile, it is obtained that each phase of life cycle has its own focus on risk factors by combing all the risk factors and risk events of China high–speed railway. In the phases of design and manufacture, the major basic risk factors are function risk, progress risk, structure risk, equipment risk, construction organization risk, safety management risk, which will lead to the duration risk, quality risk and safety risk. In the phase of operation, the major basic risk factor is safety management risk for operation and emergencies, which will lead to safety risk and social risk. In the phase of decommissioning and abandon, the major basic risk is applicability of technological, which is related to technical innovation of China high-speed railway and will influence the duration, quality and safety of a new generation of high-speed railway.

3.2 The Strategies of the China High-Speed Railway Emergency Management

Most of the people think emergency management of high-speed railway refers to the appropriate disposal policy and settlement when the emergencies happen during the operation. However, according to the life cycle, the performance of each phase influences that of the next one, meanwhile, the risk factors contained in each phase will be passed to the next phase and lead to worse safety problems of high-speed railway. So the emergency management of high-speed railway is an integrated, dynamic process that includes crisis management before and after the emergencies happen, the purpose of which is to avoid public safety emergency incidents, to minimize the hazard or eliminate such emergencies.

Table 1 The strategies of high-speed rail emergency management

Life cycle stage	Basic risk factors	Management tasks	Emergency strategies
Design and manufacture	Function risk, progress risk	Identify quality and safety risks	Early alarm before the crisis
	Structure risk, equipment risk	Enhance safety skills and emergency awareness of the staff	Drawing pre-plans
	Construction organization risk		
	Safety management risk		
Operation	Day-to-day operation Emergencies	Monitor and maintain safe operation	Emergency response disposal
		Effectively respond to emergencies	Accident analysis and settlement
		Reduce social hazard	
Decommissioning and abandon	Applicability of technological innovation	Elevate quality	Post-crisis restoration and upgrading
		Improve safety performance	

The main contents of emergency management shall include: crisis prevention and early warning, emergency plan formulation, emergency rescue and accident analysis, post-processing of the event, the construction of emergency management system and so on.

The basic targets of high-speed railway emergency management shall include: the ability to recognize and identify potential threats, to monitor and maintain the operation of high-speed rail and minimize the hazard or eliminate such emergencies; ensure response plans or strategies in case any threats (including natural disasters or emergency events) occur; assist the threatened high-speed rail to restore normal operation as soon as possible; improve the emergency awareness and safety skills of the employees so that the efficiency and effectiveness in disaster alleviation may be enhanced and operation coordination may be enhanced.

Aimed at the specific risk factors of each phase in the life cycle, the contents and targets of emergency management of China high-speed railway have their own focus and the strategies are different in each phase. Summarized as Table 1. The Specific approaches of each strategy will be discussed in next section.

4 Discussion

It is a most challenging system engineering to improve China high-speed railway emergency management, which is of great significance to ensure rapid, efficient and orderly response to all kinds of crises and unexpected security incidents in the operation of high-speed railway.

As what has been mentioned before, the performance of each phase in the life cycle of high-speed railway influences that of the next one. The risk factors contained in each phase will be passed to the next phase and lead to worse safety problems of high-speed railway. So, the front phase must be paid more attention. As we can see from the Table 1, in the design and manufacturing phases, there are more inherent risks in the high-speed railway. In another word, the phases of design and manufacture determine the operation safety of high-speed railway. It is inferred that prevention and early warning before emergencies occurrences occupy more important position in China high-speed railway emergency management.

4.1 The Approaches of Prevention and Early Warning in Design and Manufacturing Phases

4.1.1 Improve the Qualities of Designer and Constructors

It is obvious that high-speed railway is knowledge-intensive and technology-intensive, especially in the phases of design and manufacture. The two phase include project planning, feasibility analysis, design and manufacture the entire high-speed railway system, wind tunnel testing and structural testing and test run, etc. Human being is the key factor at these two phases, because most of the work at this stage is done by the wisdom of the people. It is evident that the technical capacities, attitudes, awareness, physical and mental health of all personnel involved in the design and construction of high-speed railway and to some extent will decide the level operation safety as well as implementation of the high-speed railway in the future.

Therefore, in these phases, the approaches should focus on the job security qualifications as well as knowledge and skill levels of the designers and the constructors. At the same time, scientifically organizing the constructions, strictly implementing safety rules and regulations, and vigorously strengthening the awareness and the ability of the staff for risk prevention are all efficient approach for prevention and early warning.

4.1.2 Optimize Contingency Plans Before the Formal Operation of the High-Speed Railway

As an important part of the crisis prevention and early warning, China high-speed railway contingency plans also need improving urgently. Due to the late start of the project, many state-of-the-art technologies must be the introduced from abroad. In addition, our country still have not fully mastered the structure and performance of the CRH trains, if any emergency occurs, lots of problems, such as how to evacuate the passengers, how to disintegrate the CRH train and how to carry out rescue work, cannot be rapidly solved. Therefore, formulating relevant contingency plans

for these problems is necessary for emergency management of China high-speed railway. Contingency plans should include scenario descriptions.

The contingency plans should include the assessment of the emergency response resources and capabilities, setting different levels according to the circumstances of the accident, utilizing all kinds of emergency professional rescue organizations and cooperative relations and determining the basic forms of the rescue as well as the rescue capabilities. With the detailed provisions of the plan, training and drills for unexpected emergency accidents must be strengthened.

4.1.3 The Approaches of Emergency Response in the Phase of Operation

In the formal operation of the high-speed railway, emergency management mainly focuses on the day-to-day operations and emergency security incidents. Monitoring the day-to-day operations of the high-speed railway and maintenance for the equipments will help to detect the hidden security risks in the operation of the high-speed railway and prevent the sudden occurrence of safety accidents. However, once safety incidents occur in high-speed rail operation, an emergency command center shall be set up immediately, and emergency response teams shall also be set up both at the station and on the CRH train to carry out emergency rescue and ensure the unified command and action in emergency response. For the emergency incidents that has a sever influence and is beyond the response capability of the railway management, the government shall take the leading position and set up accident rescue command center and a number of teams so as to carry out their respective missions for on-site rescue, accident settlement, medical treatment and information release, etc. Try every effort to eliminate the negative influence of the accident.

4.1.4 The Approaches of Post-crisis Restoration in the Phase of Decommission and Abandon

The tasks in this phase is similar to the phase of design, most detail of approaches will not be discussed again. However, what needs to be emphasized is that the relevant department should make good use of the decommissioned and abandoned high-speed railway equipments and carry out technological innovation and transformation with these equipments so that we may invent new technologies which may be more suitable to the safe operation of the high-speed rail, and that make contribution to the constant improvement of the safety performance of the high-speed rail.

5 Conclusion

In this study, the major risk factors in China high-speed railway is identified from the perspective of the life cycle of China via the risk network theory. Moreover, based on this, the framework for high-speed rail emergency management is raised. The main conclusions of the article are as follows:

Firstly, the main risk factors of China high-speed railway include quality risk, security risk, duration risk and social risk, all of these risk factors are under the influence of the function, structure, equipment, progress, construction organization, security management, technical innovation and other factors of the China high-speed rail project.

Secondly, the emergency management strategies for high-speed railway, according to its life cycle, can be divided into three stages which taking the design and manufacturing stage as an early warning of the crisis, the operation as emergency response disposal, and the decommissioning and abandon stage as recovery and upgrading.

Thirdly, the emergency management of China high-speed railway should focus on crisis early warning in advance to prevent the sudden occurrence of safety accidents. At the stage of crisis early warning, we should emphasize the technical ability, attitude, awareness, physical and mental health of the designers and constructors, we should strictly require the qualifications and job security awareness as well as their knowledge and skill levels for designers and constructors. Meanwhile, we should organize the operations in a scientific manner, implement safety rules and regulations, vigorously strengthen the awareness and capabilities in risk prevention, avoid project duration, quality, safety and other risks and improve crisis early warning. In addition, make urgent improvement to the contingency plans of the high-speed railway, and simultaneously strengthen the emergency response training and drills.

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