Prediction Model of Emergency Rescue time for Special Major Accidents in High-speed Railway based on GERTS Network

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Abstract. The existing emergency rescue process of high-speed railway mainly depends on the command and experience of emergency managers, and the rescue efficiency fluctuates greatly. In order to solve this problem, this paper constructs a model which can predict the time needed for emergency rescue. Firstly, the emergency rescue process of high-speed railway emergency is analyzed, then the relationship between key rescue tasks and the required time can be obtained according to the data mining of rescue cases and expert consultation, and the GERTS network model is established. Finally, the Yong-Wen line accident rescue case is simulated. The accident of Yong-Wen line was interrupted for 32 hours and 35 minutes, the number of simulations is 10000, and the average time is 32 hours. The results show that the model can accurately predict the time needed for emergency rescue and assist the rescue department to make scientific decisions.

1. Introduction
At present, as a modern means of transport, high-speed railway undertakes an important task of passenger transport. Due to the high speed and large carrying capacity of the high-speed train, in the event of an accident, it is easy to cause serious casualties and large-scale traffic jams, affecting the normal operation of the railway system. If the rescue can not be carried out timely and effectively, it will inevitably cause huge economic losses and adverse social impact.

At present, the research on the implementation effect of emergency rescue for sudden accidents of high-speed railway is relatively few, and the related research is mainly focused on the optimization and evaluation of emergency plan, the allocation of emergency resources, the implementation of emergency disposal decision and so on. Li Yang, Gao Ziyou and others\textsuperscript{1} analyzed the existing safety supervision and controlled mode of China's railway operation department, put forward the design idea of railway safety early warning system, and constructed the information platform of railway safety early warning system. Li Lei, Li Yanlai and so on\textsuperscript{2} evaluated and optimized the emergency plan of high-speed railway. For the railway emergency resource scheduling problem with uncertain demand, Wang Fuzhang\textsuperscript{3} established a multi-objective programming model, which can provide a scientific basis for resource scheduling decision-making. Tang Shisheng\textsuperscript{4} constructed the architecture and functional modules of the railway emergency rescue decision support system according to the actual railway emergency rescue.

Forecasting the emergency rescue time and assisting the rescue department to make scientific decisions belong to the emergency response stage, which refers to all kinds of emergency disposal and
rescue work in the process of emergency occurrence and development. This is the key stage and actual combat stage of dealing with emergencies. Timeliness is one of the important factors to be considered in railway emergency rescue work. Only when emergency rescue equipment and teams carry out rescue work at the first time and completed efficiently can the losses caused by accidents be reduced as much as possible. At the same time, secondary and derivative accidents can be prevented.

2. GERTS Model of Emergency Rescue for High Speed Railway

2.1. Characteristics of Stochastic Networks
The nodes contained in the random network can have different characteristics, which can be used to represent the occurrence of different types of events. Multiple activities can be introduced into the input of the node, and the conditions for the implementation of the node can also be different. It can be achieved only after the completion of all the activities, or after the completion of several activities. There can also be multiple outputs of nodes, and the output activities can be realized according to a given probability, which is similar to the need for multiple tasks in a certain stage of high-speed railway rescue. The output of the network can also have a closed loop, which can feedback the implementation of the rescue mission. The parameters can be selected by different kinds of probability distributions. Due to the different rescue tasks, the time required to complete the work obeys different probability distributions.

2.2. Determination of Random Network nodes

At the output end of the node, there are two types: positive type and probability type. In the positive output, the follow-up activities are sure to occur; in the probabilistic output, an activity implementation is selected according to the branch probability of each activity. In the network simulation, the Monte Carlo method is adopted to generate a random number from the uniformly distributed random number generator, and then the activity selection is determined according to the probability range of each branch. For example, in figure 2, if $p_1=0.3$, $p_2=0.5$, $p_3=0.2$, Then the probability range of activity 1 is $(0,0.3]$, and the range of activity 2 and 3 is $(0.3,0.8]$ and $(0.8,1]$ respectively. If the generated random number is within the range of $(0.3,0.8]$, activity b is executed, otherwise other activities are performed. Because the uniformly distributed random number is called, when multiple simulations are carried out, it can be guaranteed that the probability of each induced activity to be performed conforms to the specified value.
2.3. Random network transfer vector
Figure 3 shows the post-failure maintenance process of RBC, which is used as an example to illustrate the meaning of transfer vector. Node 3 to node 6 is the maintenance process of the power input power switch, node 4 to node 6 is the line short circuit maintenance process, and node 5 to node 6 is the maintenance process of the power module in the cabinet. Take node 3 to node 6 as an example, due to the possibility of failure again after power maintenance, there is a self-loop situation. The above figure shows that the probability of no recurrence of failure after maintenance is 0.98, and the probability of failure after maintenance is 0.02. The time needed in the maintenance process obeys the normal distribution, and the amount of resources needed in the maintenance work is 1. The rest of the nodes are similar to the above.

2.4. Parameter setting of random network for emergency rescue of high-speed railway
Due to the different causes and severity of the accident and the different environment around the accident site, the time required for the high-speed railway emergency rescue work will fluctuate under the influence of a variety of factors, and the completion of the rescue mission has a certain degree of randomness. After analyzing and mining the past rescue data and consulting experts, it is found that they are basically in line with the normal distribution of different parameters. Therefore, in this paper, the completion time distribution of the specific process of emergency rescue and disposal of high-speed railway emergency is assumed to be a normal distribution. The parameters involved in the normal distribution are obtained by statistical and expert revision methods.

3. Case analysis
3.1. Accident profile
Train D301 from Beijing South Station to Fuzhou Station and train D3115 from Hangzhou Station to Fuzhou South Station rear-ended on July 23, 2011 in Wenzhou, Zhejiang Province, killing 40 people and injuring 172 others. 32h35min was interrupted.

3.2. Establishment of GERTS Model of accident
After the accident, the personnel at the scene of the accident report the status of the accident. The dispatching and command department determines the emergency response level according to the accident situation, and reports to the corresponding departments to start the emergency, and after determining the emergency plan, mobilize various departments to carry out rescue work. The emergency rescue process is shown in figure 4.

According to the above rescue work relationship and the modeling method proposed in this paper, the GERTS network model can be established for the emergency rescue process of this accident. As this study mainly predicts the emergency rescue time, the end node is defined as the resumption of traffic in the analysis, and the follow-up work such as follow-up treatment is not considered, as shown in figure 5.

3.3. Simulation calculation of rescue time prediction
According to the GERTS network model of emergency rescue process, the model has three uncertain
output nodes, which are 9, 10 and 11 nodes respectively. The probability of subsequent events is shown in figure 5. Taking the occurrence of node 1 emergency as the starting time, the time is recorded as 0, and then the network simulation is carried out in MATLAB according to the logical relationship in the GERTS model. When the follow-up work has multiple prerequisites, they need to be completed before the follow-up work can be continued. For example, the 19 nodes can only be realized after the four processes of 9-19, 10-19, 18-19 and 16-19 are all completed.

In order to verify the rationality of the model built in this paper to predict the time needed for the completion of the rescue, the predicted results of the rescue time are compared with the actual rescue time. Figure 6 shows the simulation results of rescue prediction. The number of emergency rescue simulations is set to 10000, and the average rescue time is predicted to be about 32 hours, which is not much different from the 32h35min interrupted by this accident. And it can simulate the execution and completion of each rescue task in the emergency rescue process, so that the emergency rescue department can have a more accurate estimation of the whole rescue process and arrange the rescue...
work reasonably. It can be seen that the model established in this paper can truly and reasonably describe the railway emergency rescue process, and can reasonably and accurately predict the total rescue time and rescue process. In this paper, the rescue time predicted by the GERTS network model constructed by referring to the previous rescue historical experience data and expert consultation is basically consistent with the actual rescue time of this case, so it is considered that the model constructed in this paper can reasonably predict the actual emergency rescue time.

![Simulation results of emergency rescue GERTS network](image-url)

Figure 5 Simulation results of emergency rescue GERTS network

Through the above simulation results, the railway rescue department can have a reasonable prediction of the total emergency rescue time and the execution time and completion time of each key process at the initial stage of rescue. The prediction of the total emergency rescue time can provide a basis for the adjustment of the driving plan, so as to supervise and manage the completion of various rescue tasks in the rescue process, and assist the emergency departments to make scientific decisions.

4. Conclusion

In this paper, a prediction model of emergency rescue time for special major accidents of high-speed railway is proposed, and the GERTS network model is used to represent the emergency rescue process of special major accidents of high-speed railway. The actual rescue case of Yong-Wen line accident is simulated to prove the feasibility of the model. This model can predict the total time needed to complete the emergency rescue, provide a basis for the adjustment of the driving plan, assist the emergency rescue department to make scientific decisions, improve the efficiency of emergency rescue, reduce the impact of accidents, and resume operation as soon as possible. In the follow-up, we will analyze how to warn the emergency rescue progress according to the forecast time, in order to remind the rescue personnel to make reasonable adjustments in time or to warn against the delay of the follow-up rescue mission.

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