Study On Disaster Mitigation By Chain Scission Of Subway Disaster Chain

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Abstract： With the increase of urban rail transit system complexity, the disaster process usually show the disaster chain form, the structure presented by multiple disasters and its communication process between the two has the complex dynamic network. This paper studies the critical evaluation model of the disaster transmission process in metro disaster chain by using the universal disaster chain network in urban rail transit system.First, it constructs the evaluation index system of important degree of communication process. Secondly, based on the characteristics of the subway disaster chain, an important evaluation model of the disaster propagation process is given. In the end, an analysis of a major fire accident at king's cross station in London, England, has proved the validity of the model.

Keywords: subway;disaster chain;complex network

1 Introduction

The concept of disaster chain was first proposed in the 1990s, which is a kind of phenomenon that causes a series of disasters to occur [1], which has the characteristics of inducing nature, timing and expansion [2]. Urban rail transit system, especially the subway system, due to its relatively closed environment, can easily cause the spread of disasters and form a chain of disasters in the event of a disaster. In the subway disaster chain different disasters to the importance of the communication process, to find effective curb the spread of the subway disaster method provides a reliable basis for disaster prevention and mitigation, and to ensure the safety of subway operation is of great significance.

In this paper, the complex network model is chosen as the modeling method of subway disaster chain. Some scholars have made quite detailed studies on the use of complex networks to study disaster propagation. Weng wenguo of tsinghua university et al. [3] established a disaster spread dynamics model for some common characteristics of key lifeline systems, such as water supply network, power supply network, and transportation network. In addition, Ou yangming [4] also used the scale-free network with redundant systems to conduct relevant studies on disaster evolution. However, the above researches mainly focus on the dynamics of disaster spread, and there is no research on each process of disaster spread in the disaster chain network.

In this paper, the edge of the network is taken as the research object, and the characteristic parameters of the complex network are taken as the evaluation index. Research results show that the model can makes it clear that the important role in the transmission process in the whole metro network hazard degree and its analysis results can be applied to the subway disaster chain risk assessment and safety management, etc.

2 Evaluation model index system based on complex network.

The correlation theory of complex network was first used to describe the models of nature and system engineering [5][6].Urban rail transit of disaster chain is one primary disasters and secondary disasters and the spread of the relationship between disaster network, consisting of the disaster chain of primary and secondary disasters as a "node", the spread of the relationship between different land as "edge", so that you can be abstracted as a directed shall not be entitled to a complex network. Based on the characteristics of urban rail transit disaster chain, the characteristic parameters are screened out and quantified.

In this paper, the evaluation indexes of the important degree of urban rail transit disaster transmission are selected from two aspects. On the one hand, choose indicators that can measure the importance of the process in the current network. On the other hand, the choose that measures to remove the hazard communication process for both the size of the impact of the disaster chain network.After the selection of the characteristics parameters of a sophisticated network, it is determined that the number, the average path length, and the connectivity of the network is the evaluation index.

After the index system established, in order to build the model is convenient to build function relation and to realize quantitative evaluation, to quantify the selected evaluation index.

(1)Edge betweenness

The edge number refers to the shortest path ratio of e in the network. n/N .In the network of disaster chains, the number of connections on one side reflects the number of the shortest chain of disaster in the event of the transmission of the disaster and the ratio of the shortest chain of disasters in the entire network.Its expression is as follows:

$$B_i = \sum_{j,k \in v} \frac{n_{jk}(e)}{n_{jk}} \quad (1)$$

Where, $n_{jk}(e)$ represents the number of the shortest paths between nodes j and k passing by side e; n_{jk} represents the sum of the shortest number of short circuits between node j and node k in the network.

(2)The average path length

In a network in which the network is not authorized, the shortest path representation of node I and node j indicates the number of short path upper ways between I and j and is denoted by d=min{d_{ij}}.The arithmetic mean of the shortest path of all nodes in the network is the average path length of the network, which can be used to measure the size and capability of the network and the transmission capacity of the network. It reflects the difficulty of disaster propagation in disaster chain network.Its expression is as follows:

$$L = \frac{1}{N(N-1)} \sum_{i \neq j \in V} d_{ij} \quad (2)$$

Where, N is the total number of network nodes, and d_{ij} is the shortest distance between node i and node j.

(3)Connectivity

In the disaster chain network, connectivity reflects the degree of connectivity between different disasters, and the better the connectivity, the more easily the disaster can be transmitted in the disaster chain network.The measure of connectivity is not unique. This paper considers the characteristics of the disaster chain to the network, and chooses the sum of the smallest independent rail number between the non-adjacent nodes as the measure of the connectivity.Its expression is as follows:

$$C = \sum_{i \neq j \in V \& i,j\text{不相邻}} p_{ij} \tag{3}$$

Where, p_{ij} is the minimum number of independent rails between adjacent nodes i and j.

3 Index analysis and model selection

In this particular case, we have a particular one that has to do with the one that has no right to the network, which is to do a correlation analysis of the three indices that we have chosen, to determine the form of the evaluation model. The selected network is shown in figure 2.

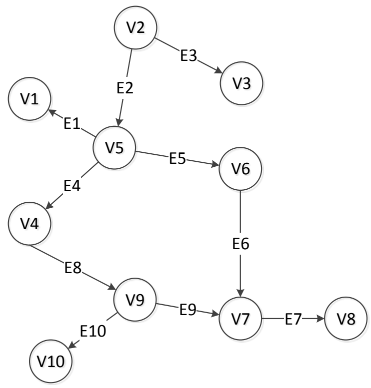

Fig.2 A General Disaster Chain Network

3.1 Calculation of indicators

According to formula (1), (2) and (3), the values of the three indexes corresponding to each edge are calculated respectively.The average path length and connectivity are calculated to measure the impact of the disaster propagation process on the existing disaster chain network. In the calculation, the value of the original network should be taken and the difference of the value after the removal of the edge is removed. For a difference of zero, it is reassigned to one half of the minimum value of the remaining edges of the index.When calculating the average path length, for convenience compared to remove a hazard communication process and the difference of the disaster chain network, this article assumes that remove edge not disconnected, And after removal of all paths on the side of the length of the assignment again, the length from the maximum path length in the original network.

Table.1 Results of Edge Betweenness, Average Path Length and Connectivity

The Evaluatioe / Number of side	Edge Betweenness	Average Path Length	Connectivit
E1	2	0.0778	0
E2	8	0.2111	6
E3	1	0.0444	0
E4	6	0.1667	6
E5	6	0.1667	2
E6	6	0.1333	2
E7	6	0.1667	5
E8	6	0.2222	8

E9	4	0.1333	3
E10	4	0.1111	3

3.2 Model selection

In statistics, there are three main forms of comprehensive evaluation model: linear weighted evaluation model, multiplicative evaluation model, and additive [7].Among them, the multiplicative evaluation model is applicable to the index with strong correlation, and the requirement of weight is not high. In order to select the appropriate comprehensive evaluation model, Pearson correlation analysis was carried out on three indexes. The results are shown in table 2.

Table.2 Pearson Correlation Coefficient

	Edge Betweenness	Average Path Length	Connectivit
Edge Betweenness	1	.917**	.750*
Average Path Length	.917**	1	.893**
Connectivit	.750*	.893**	1

Note: **. At 0.01 level (double tail), the correlation is significant.
*. At the 0.05 level (double tail), the correlation was significant.

The results show that there is a strong positive correlation between the edge betweenness, average path length and connectivity. Therefore, this paper chooses the multiplication model to evaluate the importance of the quantization process of urban rail transit disaster chain.The calculation formula of the model is:

$$V_{i\in(1,k)}=B_i\Delta L_i\Delta C_i \quad (4)$$

Among them, V is the important evaluation index of the disaster propagation process, k is the total number of edges in the disaster chain, B_i is the number of the edge I in the network,ΔL_iandΔC_i represent the average disaster path length and the change in connectivity of the network after removing the edge i.

4 The example analysis

On the basis of the above analysis, this paper takes the great fire accident of king's cross station in London in 1987 as an example to analyze. The author summarizes the forming process of the disaster chain of the subway system: the cigarette end causing the fire is located under the escalator. Due to the rapid spread of the trench effect between the escalator topography and the ventilation system, the fire caused a number of failures of facilities and equipment in the station as well as the formation of explosion and poisonous gas. The failure and explosion of equipment and other disaster events have further caused the failure of related communications equipment; The collapse and fall of the ceiling and high-altitude objects in the station caused the paralysis of the traffic system in the station and people's panic, which led to the stampede of people and the traffic jam on the road. The congestion made rescue work more difficult and ultimately caused serious casualties. Therefore, this paper constructs the subway disaster chain network as shown in figure 3:

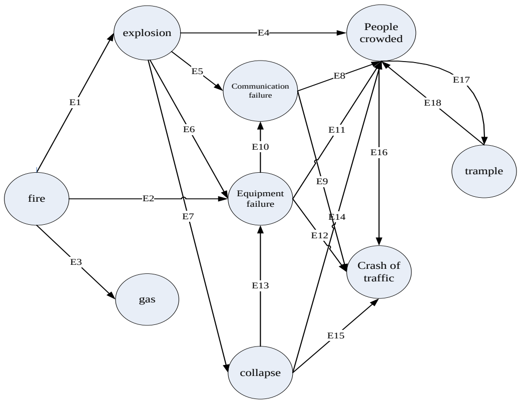

Fig.3 Metro Fire Disaster Chain Network Diagram

Calculate the betweenness of each side in the disaster chain network, and remove the edge network after disasters average path length, the change of connectivity, and according to the formula (4) to compute its important degree. The calculation results are shown in table 3:

Tab.3 Vulnerability of Metro Disaster Chain Network

edge	Edge betweenness	Average Path Length	Connectivit	Important degree
E17：People crowded→trample	5.5	0.333	5	9.1575
E1：fire→explosion	3.5	0.125	4	1.75
E10：Equipment failure→Communication failure	2.5	0.125	5	1.5625
⋮	⋮	⋮	⋮	⋮
E12：Equipment failure→Crash of traffic	2.25	0.028	1	0.063
E9：Communication failure→Crash of traffic	1.25	0.014	3	0.0525
E15：collapse→Crash of traffic	1.25	0.014	2	0.035
E3：fire→gas	1	0.069	0.5	0.0345

According to the analysis of the importance of the edge in the network, the greater the importance of one side, the greater the role of the corresponding disaster propagation process in the disaster spread. Will be ordered by the calculation results, the important degree of each chain process available from big to small in the order: E17, E1, E10, E2, E16, E8, E13, E7, E18, E4, E11, E14, E5, E6, E12, E9, E15, E3. Among them, the importance of "people crowding" and "trampling" far exceeds that of other sides. Fire - poison gas is the least important. According to incomplete statistics, the subway disaster events at home and abroad in the disaster of people because of its stampede caused panic psychology, and due to a stampede of evacuation, eventually because of not in time within the stop time is too long, the poison gas, toxic smoke and fire casualties caused by the number of disasters and accidents to the total number of casualties in the subway is as high as 75%, far higher than other causes of personnel and property losses. This is consistent with the analysis results in this paper.

Based on the analysis of king's cross station, the following Suggestions are put forward for the safety management of urban rail transit :(1) Conduct evacuation guidance. In the event of a disaster, station personnel must immediately take measures to evacuate passengers in the station to prevent chaos. (2) Beware of explosions. Put the equipment and facilities that may cause the explosion far away from the load bearing wall and passenger flow, timely find all kinds of dangerous goods carried by passengers, and timely conduct the inspection of inflammable and explosive goods. (3) Make good on-site dispatching in case of disaster. In the event of a disaster, contact the adjacent station and the train coming into the station immediately to prevent other vehicles from entering the station. Inform relevant units of emergency rescue as soon as possible.

5 Conclusion

The following conclusions can be obtained through theoretical and practical analysis:

(1)The evaluation model based on the characteristic parameters of complex network can better reflect the importance of a disaster propagation process in the network of urban rail transit disaster chain network. And through the calculation of the specific disaster chain network, we can find the targeted urban rail transit disaster prevention and reduction methods.

(2)To summarize the results of the instance analysis, it is concluded that in the normal chain of disasters, the nodes that correspond to the original disasters, the smaller nodes are more important than the other ones; In the middle node, the degree of penetration is larger than that of the node with the larger degree of entry. Intermediate node, the node degree is larger, the smaller the linked the edge important degrees is bigger, the disaster at the end of the disaster chain, the corresponding node into smaller node corresponding edge important degrees is bigger.

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