

Analysis of Errors in Subway Team Cooperation based on Complex Network

WANG Jie¹, GUO Jun¹, MA Wei-wei², GUO Xiao-hong¹

¹ School of Safety and Environmental Engineering, Capital University of Economics and Business, Beijing 100070, P.R.China ² Beijing MTR Corporation 1000068, P.R. China

Abstract. Multi-team collaboration plays an important role in subway safe operation. In order to avoid the delay and inefficiency of emergency response caused by multi-team' errors, this paper built the complex network of subway multi-team' s human factors. The complex network is constructed through thirteen types of subway emergency response. The status of events and equipment represents the node and the behavior of multi-team represents the edge in the complex network. The weight of edge ensured by the probability of a person's failure that be calculated though the VACP model. At last, the importance of node and edge in complex network of multi-team is evaluated based on the complex network theory. So the importance of events and equipment status and team's behavior in complex networks of multi-team are evaluated and sorted. The analysis results show that the screen, telephones and broadcasts are important equipment and "contacting by phone", "seeing the screen" and "adjusting the train" are important behavior in the emergency. Some measures are put forward to reduce the human errors in multi-team collaboration operation according to the evaluation results. It is meaningful to improve the safety operation of the subway.

1. Introduction

Subway operation is a huge complex system and its safe operation depends on many teams in their duties and the close coordination between each other. It is of great significance to reduce the number of people caused by multi-team cooperation. The study of human error in the multi-team cooperation is less at present and it's concentrated in the field of nuclear power, aviation and medicine. The decision-making capacity of the nuclear power plant team is qualitative analyzed in the abnormal state(Sasou,1993.1999). The cognitive error is quantitatively analyzed in nuclear power plant team through CREAM quantitative analysis(Liao,2007). The accuracy of communication is the key to reduce the mistakes of the team by analyzingthe content characteristics of operating group communication in nuclear power control room(Zhang,2015). Based on the threat and error management (TEM), someone analyzed the flow and influencing factors of the failure of the air traffic control team and put forward the countermeasures to reduce the errors (Lv,2009). Goldfarb and others believe that the individual differences in the team may lead to misunderstanding in the operating room environment further cause surgical errors(Pizzi,Neil,Goldfarb,2001). However, there are few studies on the multi-team in the subway area. Therefore, this paper constructs complex network of multi-team under subway emergencies based on the analysis of human factors and complex network theory. By analyzing the importance of complex network nodes and edge to evaluate the human factors of subway multi - team. It 's meaningful to analyze and reduce the number of the subway unexpected events from the multi-team aspect and optimize the emergency program.



2. Emergency Response of Multi - Team

Subway incidents refers to all of the accident which effect normal subway operations. The 13 categories of emergencies which often occurred are: Platform Screen Door failure (affect the operation), train failure, turnout failure (loss table), car ATP failure, ground ATP failure (abnormal red), the ground ATP failure (no display), ballast injury (lying rail), lathe fake outbound signal, the train is on fire in the station, the train is on fire in the tunnel (can enter station), the train in the tunnel fire (can not enter station), Platform Screen Door folder people, the train hit the collision. Subway operating system multi-team is mainly related to the cooperation emergency response between the teams. It includes drivers, person on duty at train, master on duty at station, decision-making dispatcher, officer on dispatch duty, passenger dispatcher, staff at signal floor and so on.

The Platform Screen Door failure is regarded as an example and the emergency flow chart is as follows.

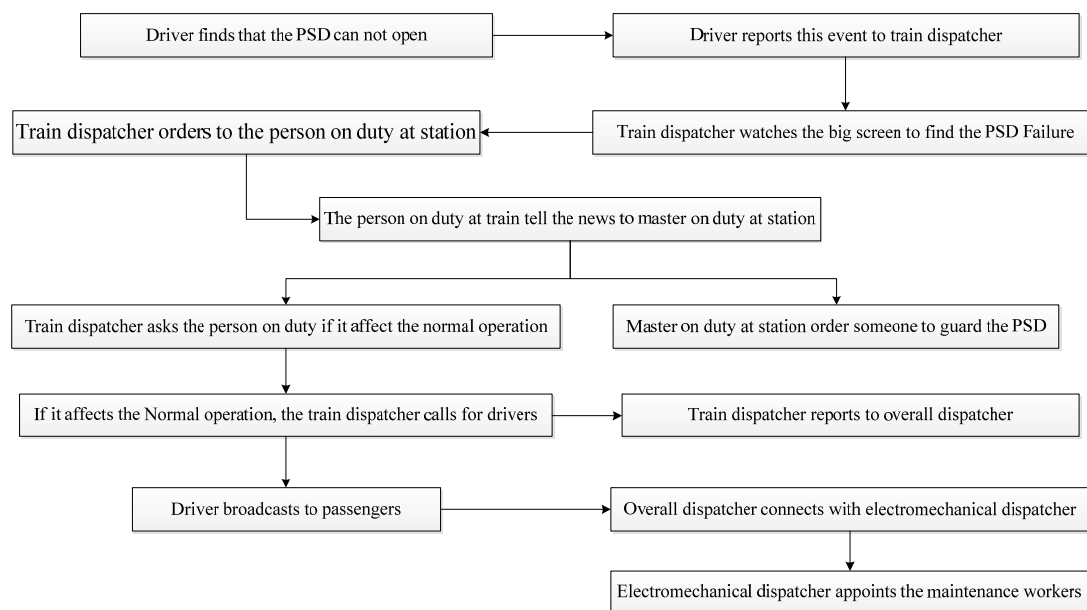


Figure 1. The emergency response process of PSD failure

3. The construction of multi - team coordination complex network

3.1 "Node" and "Edge" of complex networks

The complex network is constructed based on the complex network theory. The complex network "nodes" and "edges" is ensured according to the emergency response process. The state of events and devices in the emergency response process represents the "nodes" of the complex network. Each node is replaced with number. For example, "1" represents the event of PSD failure. "2" represents the ringing of phone... It is not enumerated a total of 286 nodes. The relationship between nodes is the behavior of the team in the emergency flow chart. It's the "edge" of the complex network. There is a directional connection between the event and the device and the probability of the group's behavioral errors is existed. So the complex network of the subway team is the directed and weighted network.

Table 1. Nodes and Edges in Subway multi-team complex networks

Number of node	Node	Edge	The linked node	
1	The PSD failure	The driver dials the wireless phone	1	2
2	Wireless telephone is ringing	Hear the phone	2	3
3	The wireless phone continues to ring	Train dispatcher picks up the phone	3	4

4	Train dispatcher knows the PSD failure	Train dispatcher hangs up the phone	4	5
5	The phone is in its original state	Train dispatcher checks big screen	5	6 10
6	Train dispatcher finds the PSD failure			
7	Dispatch telephone is ringing	The person on duty at station calls to the train dispatcher	1	7
8	Dispatch telephone continues to ring	Train dispatcher hears the phone	7	8
9	Train dispatcher knows the PSD failure	Dispatch picks up the phone	8	9
10	Dispatch telephone is in its original state	Hang up the phone	9	10
...	...	...	...	
286	Train dispatcher knows the train hit person	Hang up the phone	286	229

3.2 VACP model and the weight of edge

The VACP model argues that operational tasks can be accomplished by resources such as vision, hearing, cognition, and movement. It defined the level of requirements for information processing resources of pilots (McCracken, Aldrich, 1984). The higher the level of the behavior, the greater the difficulty and the more prone to mistakes. Therefore, this model is introduced into the subway emergencies. The VACP resource requirements level values the weight of the "edge" in complex networks. The complex network is constructed. The main groups of each team due to the probability of failure in Table 2.

Table 2. The probability of multi-team's human errors

The behavior / action of each team member	VACP level / the probability
The driver / train dispatcher calls the wireless phone to the train dispatcher / driver	5.8
Train dispatcher calls to the overall dispatcher / electromechanical dispatcher	
Train dispatcher / driver / the person on duty at train / overall dispatcher calls to hear the phone	4.2
Train dispatcher / driver / overall dispatcher lifts / hangs up	4.6
the person on duty at train / train dispatcher calls to train dispatcher / the person on duty at train	6.5
The person on duty at train / train dispatcher calls and answers phone	2.2
Train dispatcher checks big screen	5.0
Job announcements / inquiries / answers and so on	4.9
Train dispatcher / driver / the person on duty at train orders recitation (code, memories)	5.3
Driver / station guard / the person on duty at train presses button	2.2
PSD is opened manually and so on	4.6
Driver / station personnel guides passengers	6.8
The person on duty at train contacts with master on duty at station	1.0
Maintenance workers rush to the point of failure	3.7
Repair the PSD	4.6
The station manager calls 119,120	4.6
Get off at the station	1.2

3.3 multi-team collaboration complex network

The 286 "nodes" and "edges" of the complex network are determined. The direction between the two nodes and the weight of the edge are ensured by analyzing the emergency response process. Using NetworkX to build the complex network of the subway group.

4. subway multi-team complex network assessment

The importance of event and equipment status and multi-team cooperative behavior in complex network are evaluated through six evaluation indexes according to the importance evaluation method of complex network theory and the NetworkX software.

4.1 Importance of node assessment

The "node" in a complex network model of a complex group represents the status of each event and equipment. In the study of node importance, the evaluation indexes are degree centrality, the betweenness centrality and clustering coefficients.

The degree centrality reflects the impact of various types of emergencies and equipment in the network. The greater the degree of the node, the greater the importance of it. The betweenness centrality represents the control of the network traffic. The shorter the path through a node, then the more important of the node. The clustering coefficients indicates the tightness of each node in the network. The analysis results of degree centrality for complex network nodes in Table 3. The node importance is sorted as follows Table 4.

Table 3. The analysis results of degree centrality for complex network nodes

Number of node	Node sorts by edge-betweeness	The meaning of node	Sorting
15	0.12631578947368421	The dispatch phone is restored to its original state	1
10	0.11228070175438597	The dispatch phone is restored to its original state	2
05	0.09473684210526316	The phone is restored to its original state	3
53	0.09473684210526316	Resume operation	4
12	0.07719298245614035	The dispatch phone continues to ring	5
11	0.06666666666666667	The dispatch phone rings	6
7	0.06315789473684211	The dispatch phone is ringing	7
8	0.06315789473684211	The dispatch phone continues to ring	8
20	0.06315789473684211	The phone is restored to its original state	9

Table 4. The analysis results of node for complex network

Sorting	Node sorts by edge-betweeness	Node sorts by the edge's meaning	Node sorts by the network efficiency
1	15 The dispatch phone is restored to its original state	51 Train dispatcher adjusts the number of cars	52、112、125、136、162 Shunt to large spacing line to fill the car / find a large screen with red light / find a large screen without red light / train dispatcher orders to follow-up train to be withholding / broadcast information to passengers
2	10 The dispatch phone is restored to its original state	10 The dispatch phone is restored to its original state	18、86、124 The driver gets the broadcast information / Train dispatcher determines the number of online trains / Person on duty at train reports that signal has been repaired
3	05 The phone is restored to its original state	05 The phone is restored to its original state	32 The dispatch phone is restored to its original state
4	53 Resume operation	16 Radio phone ring	49、154、177 The phone is in the original

			state / Train dispatcher finds the signal of the train in rash advance / Person on duty at train reports that the risk of exclusion and it can be opened to traffic
5	12 The dispatch phone continues to ring	226 The phone is restored to its original state	6 Train dispatcher finds the platform screen door failure
6	11 The dispatch phone rings	15 The phone is restored to its original state	11 Dispatch phone rings

4.2 Evaluation of edge importance

The evaluation of edge importance is analyzed the importance of the behavior of the group of people. There are three kinds of evaluation indexes of "edge" importance: edge-betweenness, edge-betweenness centrality and network efficiency. Edge-betweenness refers to the number of shortest paths passing through the edge. The larger the number of edges, the more times the number of nodes in the network passes through the edge. It can be used to describe the impact of team behavior on emergencies. The edge-betweenness centrality is the ratio of the number of paths of the network to the number of paths passing through the center point. The greater the number of sides passed, the greater the edge-betweenness centrality, the more important the edge. Network efficiency refers to the sum of the weight of all edges and the ratio of the shortest path length. The amount of reduce of network efficiency after deleting an edge is regarded as an indicator for evaluating the importance of connecting edges in weighted networks. The following Table 5 is a result of the analysis of the complex network edge of the subway team.

Table 5. The analysis results of edge for complex network

Sorting	Edge sorts by edge-betweenness	Edge sorts by edge-betweenness centrality	Edge sorts by the network efficiency
1	10-154 Train dispatcher sees CCTV	151-7 Person on duty at train calls the dispatch phone	113-114 Person on duty at train detects track; Fire fighters check for danger
2	5-167 Driver presses the radio button	68-51 Train dispatcher adjusts the train	10-53 68-63 Train dispatcher adjusts the train
3	10-53 Train dispatcher adjusts the train	69-7 Person on duty at train calls to the line train dispatcher	60-61 (Direct driver) fault car back to the garage
4	5-154 Train dispatcher sees CCTV	71-11 Train dispatcher calls to the person on duty at train	49-53 32-51 Train dispatcher adjusts the train
5	20-51 Train dispatcher adjusts the train	69-71 Train dispatcher sees CCTV	133-7 Person on duty at train calls to the train dispatcher
6	15-16 Train dispatcher to call the driver	10-133 Train dispatcher sees CCTV	271-272 Train dispatcher calls to the person on duty at train

4.3 Evaluation results and application analysis

The node importance assessment indicates that "The phone is restored to its original status" "The status of screen" and "The broadcast" in the complex network occupy important positions. The entire

network will be paralyzed once these points are removed. So the status of phone, screen and broadcast should be noticed. The edge importance assessment indicates that “View CCTV”, “Press the radio button” and “Train dispatcher adjusts the train” are the important behavior of stuff. These behavioral errors are more likely to lead to accidents. "Detecting orbit" plays a decisive role in the ground event of ground ATP failure. Some corresponding measures are proposed to reduce human error:

(1) Workbench buttons of dispatch team should be designed reasonably. Train dispatcher's workbench is complex and each button has a different function. Train dispatcher needs to contact each team by phone when an emergency happens in the subway. So the phone buttons which be in common can be set reasonably to prevent the wrong button to extend the emergency response time. Such as dispatch phone, driver phone, etc. For example, person on duty at train as the only team can be linked with the Train dispatcher, so the phone should be set in the place at their fingertips.

(2) The screen design takes into account human visual. Train dispatcher and person on duty at train can pay attention to the screen when the emergency happens. Then they could determine the type of event in the first time and take reasonable emergency measures to avoid more serious consequences.

5. Conclusion

(1) The relationship among the teams in subway emergency showed a complex network structure. Building and quantifying the multi-team collaboration complex network in subway emergency according to the emergency response process and VACP model to calculate the probability of human error. "Node" indicates the status of event and equipment and "edge" indicates the behavior of each team.

(2) According to the six indexes of complex network's importance assessment, the status of events and equipment and multi-team cooperative behavior are evaluated and sequenced. And then the effective measures are put forward to reduce the number of human mistakes after analyzing.

(3) Due to the distribution of the team duties in subway is similar, the multi-team cooperation complex network proposed in this paper has universal adaptability. It is of great significance to reduce the failure of the subway team.

Conflict of Interest

The author confirms that this article content has no conflict of interest.

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