Study on the Evaluation of Urban Rail Transit Emergency Management

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Abstract: Rail transportation has become a city of a standardized equipped, has become essential to the residents living part, so urban rail traffic in the event of failure, will greatly affect the residents life, resulting in a large number of passengers stranded. This paper on urban rail transit station traffic planning were analyzed and evaluated, so that you can in the disorder of urban rail transit emergency, improve the evacuation efficiency, greatly reduces the failure effect on the lives of the residents. This paper first analyzes the impact of the event on the outside of the station, and introduces the common means of traffic management. Then, this paper studies integrated simulation method and chooses key evaluation indicators, thus use the order of preference by similarity to ideal solution to evaluate the traffic management plan based on simulation. In this paper, Jiangsu city traffic as an example, through a large number of cases, the empirical results show that the scheme 2 is the most effective, which provides a reference for urban traffic management.

Keywords: Emergent events; Urban rail transit; Trafficmanagement outside the station; Simulation evaluation

1. Introduction

Urban rail traffic incidents mainly include: fire, explosion, gas attack, earthquake, bad weather, train derailment, rail transportation interruption, unexpected large passenger flow, etc., these accidents are sudden public events. This paper studies on event of disruption of rail line, this event means that section of URT route is interrupted, which rail transit train cannot run on the section. Emergent events will cause a large number of passengers stranded, which shall be evacuated by ground public transportation. Traffic management measures around the URT station should be taken, which can ensure passengers safely evacuated and promote emergency vehicles to carry out the evacuation and rescue work. Urban public traffic prevention and management measures directly affect the treatment effect of the accident, so this paper is very necessary to pre evaluation and analysis of these preventive measures.

The purpose of this paper is to evaluate the efficiency of urban rail transit management plan prevention measures. The paper is organized as follows: firstly, traffic impact was analyzed in the emergent events, and traffic management plan was illustrated; then, the evaluation method was presented, which is based on the simulation; furthermore, evaluation process was illustrated through a case; finally, we offered the summary and explanation to the conclusion, and gave an outlook to the future research.

2. Researches of Traffic Management when Emergency

Traffic evacuation is mainly divided into car evacuation and bus evacuation, and the station traffic management evacuation is a traffic evacuation strategy. Passengers are mainly evacuated by buses in emergent events of URT; therefore, we focus on bus evacuation in our study. For the research of bus evacuation in emergent events of URT, it is mainly in bus service replaces URT service. Kepaptsoglou and Karlaftis [4] propose a method ological framework for planning and designing an efficient bus bridging network. Darmanin et al. [5] propose disruption recovery strategies for the specific case of the existing bus routes of the Melbourne metro system. Jin et al. introduce a localized rail-bus integration approach aimed at enhancing the urban transit rail networks resilience to disruptions. In the past, a new method based on optimization is proposed, which can effectively deal with the unexpected events in urban rail transit.

Karlaftis et al. proposed for other traffic evacuation, mainly to study the optimization of special passenger bus service, and develop a programming model to obtain the best progress and vehicle types. Carson and Bylsma present a mathematical model of bus dispatch for special events, which the minimum bus travel time is taken as the optimized object. From the above, the researches mainly study on bus evacuation strategy and scheduling optimization model, but bus evacuation research with computer simulation is less, which lacks accuracy in effect assessment of strategy application.

Huang , by showing the exodus V4.06 and Smart fire v4.1 to assess the risk of a metro station in Shanghai. This experiment is to study the evacuation of passengers.

Wang and Chen use any logic to study the influence on evacuation time indifferent passenger evacuation simulation scenarios. Liuand Wu use Simulex to carry out evacuation simulation analysis of fires. The object of researches is passenger evacuation simulation inside the station, which does not combine with passenger evacuation simulation outside the station; therefore, these integrations are not proposed. In addition, in the event of disruption of rail link, traffic management plan shall consider the impact on background traffic, so traffic management plan evaluation needs to analyze comprehensive influence on traffic outside the station. In view of the above analysis, it need further research that how to combine simulation and comprehensive evaluation to evaluate traffic management plan.

3. Traffic Impact Analysis in Emergent Events of URT

In emergency events of URT, traffic outside the station mainly consists of passengers, emergency vehicles, and general vehicles. Emergency vehicles are divided into emergency buses and emergency rescue vehicles, as we can see from the Table 1.

Table 1. Traffic composition outside the station

Composition part	Demand character	Priority level
Passengers	Quickly and safely arriving at destination	
Emergency buses	Quickly entering and exiting the traffic area outside the station	Partial priority or absolute priority
Emergency rescue vehicles	Quickly arriving at rescue scene	Absolute priority
General vehicles	Smoothly and orderly running, as far as possible without interference	No priority

If the event occurs similar to the train delays such emergencies, then a large number of passengers will not be able to evacuate, and this time led to the crowded platform, but also to the safety of life caused a lot of damage. In this situation, some of passengers will give up URT to choose ground public transportation. Emergency rescue vehicles will arrive at the scene to carryout rescue and maintenance work, such as police car, ambulance car, tool car, and so on. Besides, as background traffic, general vehicles shall be an important part of traffic outside the station.

To ensure the normal operation of traffic outside the station, it should make transfer passengers convenient, guarantee emergency buses quickly transport passengers, and make general vehicles running smoothly and orderly. The influence factors of traffic operation mainly include passenger traffic demand, the capacity of emergency bus, and the capacity of intersection and road. These factors are closely related to traffic management plan outside the station.

4. Traffic Management Plan Outside the Station

When emergent events of URT happen, firstly, URT emergency management department adjusts train operation scheme according to specific circumstances, generally takes part route on both sides of the interruption interval, which choose turn back station to turn back, besides, it can adopt bidirectional operation on single track; then, the URT stations implement passenger flow organization, which guides passengers quickly and to be safely evacuated; furthermore, traffic management department implements traffic management plan outside the station, which arranges for passengers to use ground transportation to reach destination, and determines whether to use bus bridging according to passenger demand.

In addition, the passenger choice behavior in the emergency event is mainly divided into the following aspects:(1) choosing other metro lines to reach the destination; (2)choosing shuttle bus to reach the destination; and (3)choosing other traffic modes to reach the destination, such as taxi. The shuttle bus is a major traffic modes for passengers transfer to ground traffic, so traffic management outside the station should focus on this kind of passengers who choose shuttle bus.

For traffic management plan outside the station, it consists of three main aspects: passenger flow organization outside the station, emergency bus organization, and road traffic organization.

5. Evaluation Method Based on Simulation

5.1. Simulation Model

This paper describes the simulation traffic management model, showing the evaluation of urban transport facilities, such as Figure 1 in this paper, the simulation of traffic management needs to combine the train operation and the station passenger flow. Train operation adjustment simulation needs to finish train operation diagram adjustment for emergent events. Station passenger flow organization simulation needs to finish evacuation simulation for passengers transfer from station platform to outside of the station. Traffic management simulation is mainly for road and intersection traffic organization, emergency buses in and out of the bus stop, and organization for stop and parking. We can get evaluation indicators through simulation results, then evaluate the traffic management plan.

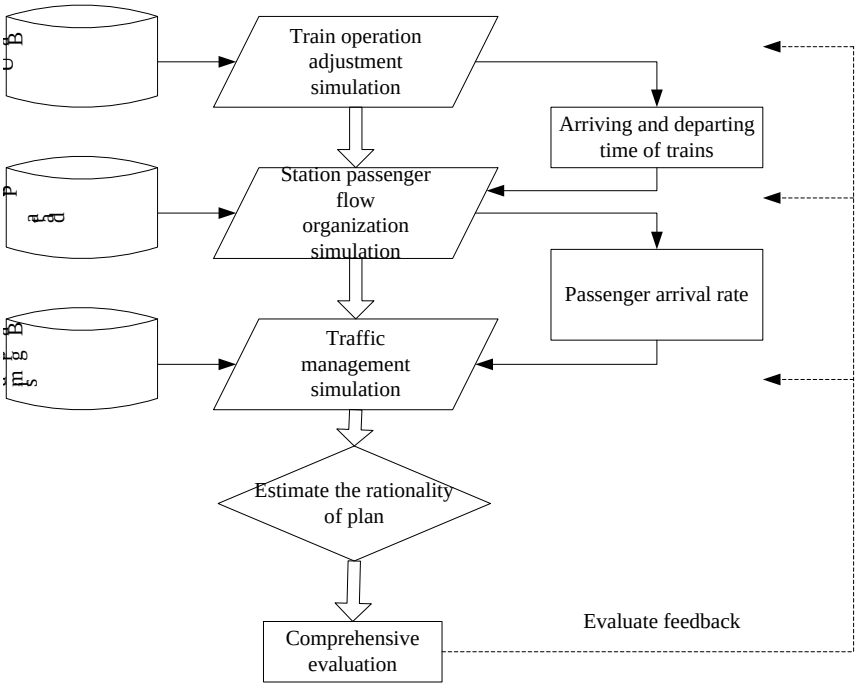

Figure 1. Simulation logical model of traffic management outside the station

According to Figure 1, the input parameter of traffic management simulation is based on train operation adjustment simulation and station passenger flow organization simulation. The main steps of the simulation are as follows: (1) Arriving and departing time of trains can begot through train operation adjustment simulation. (2)Combining with passenger flow data, passenger arrival rate can be got through station passenger flow organization simulation. According to the rate, the number of emergency buses and departure interval can be determined, which are the key input parameters for traffic management simulation. (3) We can simulate the traffic management outside the station with these parameters.

In addition, the input parameters for the simulation areas follows. As for train operation adjustment simulation, the input parameters mainly include rail line data, rail transit station data, and signal system data; as for station passenger flow organization simulation, the input parameters mainly include the station building layout data, passenger flow data, and passenger characteristic data; as for traffic management simulation, the input parameters mainly include road network data, traffic demand data, traffic management, and control data.

5.2. Evaluation Model

It shall be first considered that how to quickly evacuate passengers to safe destination in emergency events of URT, so the capacity of the emergency evacuation shall be the primary indicator to estimate the rationality of plan, unreasonable plan is out of our study. The capacity of the emergency evacuation P means the number of passengers evacuated per hour, which is calculated by the following expression:

(1) n is the simulation time, T the simulation cycle (h), Ni the number of passengers evacuated in simulation cycle.

The main body of traffic management includes evacuation passenger, emergency bus, and general vehicle. According to the three main bodies, we choose comprehensive indicators that can be available through simulation ,which as tabulated in Table 2.

Table 2. The evaluation index system of traffic management outside the station in emergent events of URT

First-grade indicator	Second-grade indicator
The service level of evacuation passenger	The biggest passenger flow density at bus waiting area
	Average waiting time
	Average queue length
The running condition of emergency bus	Average running speed
	Average delay
	Average queue length
The running condition of general vehicle	Average travel speed
	Average delay

Traffic management plan outside the station is evaluated through a way for the combination of individual evaluation and comprehensive evaluation. At first, we estimate the rationality of plan. Then, we synthetically evaluate reasonable plan by TOPSIS model.

The technique for order of preference by similarity to ideal solution (TOPSIS) is a multi-criteria decision analysis method , which was originally developed by Hwan

and Yoon in 1981 with further developments by Yoon in1987, and Hwang, Lai and Liu in 1993. Besides, there are other comprehensive evaluation models, such as AHP, FCE, DEA, and so on, but TOPSIS model has the advantage of simple calculation process, and no strict requirements for sample size and distribution. However, it will lead the evaluation result unstable because of subjective weight. Therefore, we determine the weights of evaluation indicators with entropy evaluation method, so as to avoid subjectively determining weights. The following specific introduces the new TOPSIS model.

6. Case Analysis

We chose the metro accident case in Shanghai Metro Line2 for analysis. Assume that the rail line disruption happens in Jiangsu Road station to West Nanjing Road station section. According to Shanghai Metro Emergency Response Plan , Metro emergency management department shall take a part route running mode in East Xujing station to Jiangsu Road station section, and People's Square station to Pudong International Airport station section.

6.1. Determining Traffic Management Area Outside the Station

We chose Jiangsu Road station as the object of study, which is the turn back station that is responsible for emptying all the passengers, so it has a great influence on traffic operation outside the station. Jiangsu Road station is located in Changning District of Shanghai, which is the transfer station that includes Metro Line 2 and Metro Line11. In order to make study more targeted, we referenced the standard about traffic impact assessment scope in Transportation Impact Analyses for Site Development and then determined the traffic management area (as shown in Figure 2). In the area, Line 11 station is located in Jiangsu Road, and Line 2 station is located in Yuyuan Road. There are bus stops around No. 1/3/5 subway exit, No. 3 bus stop is far from No. 8 subway exit. In addition, there are two bus routes through Jiangsu Road station to People's Square station section, which parallels the Metro Line 2.

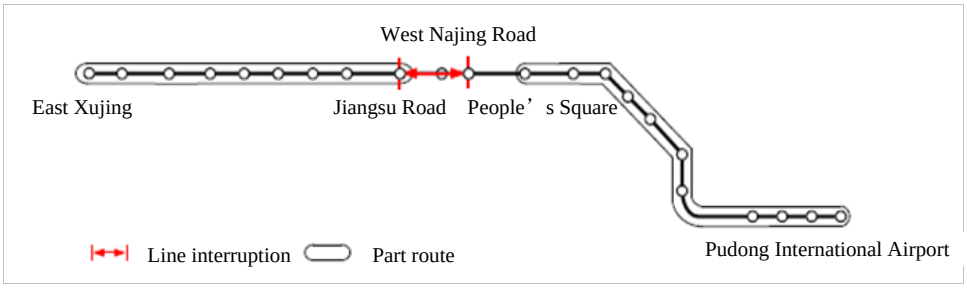

Figure 2. Illustration of metro accident case in Shanghai Metro Line 2

6.2. Traffic Management Plan Design

Jiangsu Road station is the turn back station that is responsible for emptying all the passengers, so bridging passenger flow demand is mainly decided by the number of passengers that the train empty when it arrives at the station, and the proportion that passengers choose bridging bus. The number of passengers can be calculated by passenger flow OD and arriving and departing time of trains; the calculation of the proportion that passengers choose bridging bus can refer to our previous research , this research is based on passenger travel behavior characteristics in emergent events of URT, which used the result of passenger travel behavior survey and Stated Preference survey as basic data and proposed passenger behavior distribution Logit model. We chose cost, SDB, and MRSQ as influencing factors, and calculate the utility value of three modes (URT, bus, and other modes). Then, the results were imported into Logit model. We can get selected portion of three modes, respectively, as 75, 14, and 11 %.Finally through station passenger flow simulation, we can get bridging passenger flow demand as 2082 people per hour in Jiangsu Road station.

For the design of traffic management plan outside the station, it should be considered from the following four quickly; secondly, passenger evacuation should be mainly through public transportation, thirdly, it can implement traffic separation in the area; lastly, minimizing the impact on background traffic. In view of this, we proposed three representative traffic management plans; design logic of the plans is shown in Fig. 5. In the figure, emergency bus priority level reflects passenger evacuation efficiency and the influence degree on general vehicles reflects the degree of background traffic disturbed. The higher emergency bus priority level shows that traffic management was more biased toward to bus transportation; therefore, influence degree on general vehicles is higher. In addition, emergency rescue vehicles have strict priority, which do not exist plan optimization problems. points: firstly, ensuring passenger evacuation safety.

7. Conclusions

Traffic management objects should have the right to share road infrastructure, so the capacity should be orderly distributed under a certain space–time condition, which meets the demand of each object to finish the evacuation task. In this research, we studied on traffic management plan evaluation outside the station with simulation, compared the merits of different plans. Firstly, we analyzed conversion process from metro passenger flow to bus traffic flow. Then, we developed logical model of traffic management simulation and presented transitive relation among different simulation types. In addition, we extracted key indicators around the three objects: passenger, emergency bus, and general vehicle. Finally, in the case of Jiangsu Road station, this paper designed three representative plans, the results showed that the second ‘‘partial priority plan’’ is optimal through evaluation the method based on simulation, which provides decision support for URT emergency management. At the same time, we conducted sensitivity analysis for bridging passenger flow demand, we can draw a conclusion that when passenger demand is small, we should implement ‘‘no emergency traffic management plan’’, but when passenger demand is large, we should implement ‘‘partial priority plan’’ or ‘‘absolute priority plan’’. Its further research is study on train operation adjustment method in disruptions of URT networks, which cooperates with traffic management plan to make the evacuation result best.

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