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The Formation, Propagation and Prevention of Mass Passenger Flow Events in Rail Transit Stations

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Abstract

This article mainly from the rail transit passenger flow event production, transmission and prevention of the research in three aspects, first of all, through consulting and analyzing research scholar of rail transit passenger flow of events related research results, rail transport large passenger flow is given the quantitative judgment of the incident, the rail transit passenger flow events carried out reasonable classification and to explore its causes. Then, according to the improved SIR model, the scope of influence of large passenger flow events can be more accurately planned and grasped, so that more targeted measures can be taken to improve the service level.

Keywords

Rail transit, large passenger flow, planning.

1. Introduction

With the continuous development of China's social economy, more and more traffic trips are required in our life. In the traditional sense, the ground transportation has been unable to meet people's demands, so now many cities are using rail transit as the main urban comprehensive transportation system. According to statistics, more than 30 large and medium-sized cities in China operate 133 rail transit lines, totaling about 4,153 kilometers. Although China's urban rail transit construction trend is good, but the passenger flow demand is far higher than the rail transit construction, so to complete the transport task of large passenger flow under the condition of ensuring safety has become a research hotspot in the transportation industry. By studying the occurrence, propagation law and coping strategies of mass passenger flow events in rail transit stations, specific measures can be taken to deal with mass passenger flow events, so as to help rail transit improve its quality level and give better play to its advantages of strong transport capacity and good punctuality.

2. Research Progress

Zhou Yanfang et al. [1] elaborated the definition of peak passenger flow transmission of urban rail transit, the factors affecting the transmission, and the influence of large passenger flow transmission, and finally gave the method of quantitative analysis of the influence. Zhang Lin [2] improved the identification and tracking technology of passengers in subway stations, built a rail transit passenger flow database, and realized the accurate evaluation, real-time monitoring and dynamic display of passenger flow safety with the help of it. Liu Xiaoxia [3] based on the theory of the spread of infectious diseases with sudden large passenger flow peak rail transit network transmission model studied the influence of a large passenger flow of urban rail traffic network. Cao Zhichao [4] analyzed the causes of metro large passenger emergency and explains the theory of the emergency policy support and the principle, and with the aid of satisfaction evaluation model of emergency strategy is evaluated. Tang Qiaomei [5] studied the

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relevant organizational response methods of urban rail transit system under various large passenger flow states, and elaborated the causes and characteristics of the occurrence of large passenger flow in urban rail transit, and also elaborated the causes and classification of the formation of large passenger flow. Ling Qiao [6], under the background of the gradual network operation of rail transit lines, conducted an in-depth study on the emergency organizational measures for the sudden passenger flow of urban rail transit from two perspectives, namely, the organization optimization of rail transit station passenger flow and the organization optimization and adjustment of vehicle transportation. Zhu Wei [7] analyzed the causes of mass transit passenger traffic events and the law of their propagation and diffusion in network operation, and finally put forward some countermeasures to deal with mass transit passenger traffic events.Through consulting relevant literature, it has many scholars have conducted research on rail transport large passenger flow, this paper based on the definition of large passenger rail transit station events, a quantitative analysis of the reasons for the formation of large passenger flow events and its transmission mechanism of the impact of rail transit network, on this basis to explore possible coping strategies, hope will be based on the multi-agent rail transit passenger flow propagation process as the research key, by SIR classical model to the improved model is put forward to the influence of traffic incidents have more accurately, and can be more targeted measures to improve the service level. Thus, it provides support for the operation and management of urban rail transit system and helps improve the service level of urban rail transit.

3. Study on the Large Passenger Flow of Urban Rail Transit

3.1. Definition of Mass Passenger Flow of Rail Transit

The definition of the so-called mass passenger flow of urban rail transit means that due to some factors in the operation of urban rail transit, the number of passengers at a rail transit station within a certain unit time exceeds the passenger flow permitted by the design of the station, and the concept of mass passenger flow of urban rail transit continues to increase.Through investigation and analysis.

some researchers have obtained the specific parameters of traffic flow in the waiting area (platform and station hall) of rail transit station at different service levels and the classification table of passenger flow at the station, as shown in Table 1 below:

Table 1. Traffic flow parameters of waiting area at different service levels

The service level	Density (person/m2)	Per capita space (m2 / person)
A	<0.61	>1.64
B	0.61~0.85	1.18~1.64
C	0.85~1.24	0.81~1.18
D	1.24~2.11	0.47~0.81
E	2.11~3.78	0.26~0.47
F	>3.78	<0.26

In rail transit station, station hall, channel platform as the research object, in two or more than two train operation interval, with the continuous entering the station of passenger flow, leading to the subway station in a specific area of passenger average density at 2.11 / m2 or when (that is, the service level in the two train operation interval maintain under D levels), then the event can be said the rail transit passenger flow. The classification table of the degree of large passenger flow in the station is shown in Table 2, where CA stands for the reasonable capacity

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of the platform, MA stands for the maximum capacity of the platform, and when the total number of people waiting on the platform is lower than 70% of the reasonable capacity of the platform, it is the regular passenger flow of the station.

Table 2. Grade table of station large passenger flow

The scope of	The degree of
0~0.7CA	Regular passenger flow
0.7~0.8CA	Two large passenger flow
0.8CA~MA	First class large passenger flow

3.2. The Reasons of Large Passenger Flow Are Introduced

Analysis of reasons for the formation of large passenger flowNo matter what kind of large passenger flow incidents occur, they can be explained from three aspects: the number of people entering the station per unit time, the train capacity and the internal capacity of the rail transit station. The formation mechanism of large passenger flow events can be divided into three types:

3.2.1. Judgment of Large Passenger Flow Events

After studying the qualitative explanation of the correlation of large passenger flow events, it can be seen that the forming conditions of large passenger flow events are closely related to the three factors of passenger flow arrival volume U, train transport capacity W and rail transit station internal capacity V

When $U \geq W + V$ This indicates that the evacuation function of the station fails to meet the travel needs of passengers at this time, and the situation gradually deteriorates. Therefore, it can be judged that large passenger flow events begin to occur at this time

When $U \leq W + V$ At this time, the evacuation function of the station plays a normal role, and there is no obvious backlog of passengers in the station. Therefore, it is judged that the large passenger flow event will not occur at this time.

3.3. Analysis of the Propagation Characteristics of Large Passenger Flow in Urban Rail Transit

3.3.1. Causes of Large Passenger Flow Events

The main function of rail transit station is to realize the collection and distribution of all kinds of passenger flows. It is the most concentrated and complex place for the interaction among passengers, trains, stations and lines. After entering the station through the gate, passengers walk a distance to the platform, wait at the platform, and then board the train to their destination. Normally, passengers can smoothly boarded the bus left, the station passenger flow organization and orderly, but sometimes there will be three special circumstances: 1) the train has a certain capacity limits, the less in the passenger train platform, all the passengers boarded the bus, when waiting passengers there are, there will be a part of the passengers cannot smoothly boarded the bus, and passengers stranded - "take", left by the continuous accumulation of station traffic continues to grow and more than allow traffic; 2) When the train is interrupted, passengers are constantly stuck in the station, resulting in a backlog of passenger flow, which then exceeds the allowable passenger flow of the station; 3) An explosive influx of passengers into the station in such a short time that the station is "filled to capacity" before the train arrives. See Figure 1 for the analysis of the passenger flow organization process and the generation process of large passenger flow events. According to the definition of mass passenger flow events in rail transit stations, mass passenger flow events will occur in all of these three situations. In addition, a large number of rail transit passengers in the station due to psychological abnormalities in emergency, such as tension, conformity, pushing and other

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behaviors, will also have an impact on the formation, intensification and evolution of mass passenger flow events. By the definition of large passenger flow events for the rail transit station and a process of qualitative analysis, you can see that whether it is a big event large passenger flow, or accident/fault big events or large passenger flow peak hour passenger flow, its are formed mainly depends on the capacity of the station, the station transport capacity and passengers to flow three indexes, the quantitative relation between and among decide whether large passenger flow events happen.

3.4. Diffusion Mechanism of Mass Passenger Flow Events in Rail Transit

The diffusion mechanism of large passenger flow events is mainly reflected in the diffusion in time and space and the initiation of secondary and derived events after the occurrence of events.1) Spatial and temporal diffusion The diffusion propagation in the time dimension mainly refers to the propagation and continuation at the time level after the occurrence of a large passenger flow event, specifically including the duration of the impact of the initial large passenger flow event and the duration of the impact of secondary events caused by the initial event.2) Diffusion of spatial dimensions The spatial diffusion propagation mainly refers to the propagation and continuation at the spatial level after the occurrence of a large passenger flow event, which specifically includes the influence on the surrounding area of the initial large passenger flow event, the adjacent rail transit station, and the influence of the movement of the train on the rail transit line network on other stations.3) Influence of derivative events The impact of large passenger flow events derived events refers to: large passenger flow event propagation process not only includes the physical aspects of simple transmission of spacetime dimensions, there are similar to the sequence in the process of chemical reaction with or parallel many based on the secondary reaction at the same time, then large passenger flow events will continue to spread with the help of these primitives secondary reactions.

3.5. Chemical Processes of Propagation -- Secondary Effects

In the chemical process of combustion, new substances are formed after the chemical reaction of combustion substances and combustion-supporting substances under certain temperature and pressure. Similarly, large passenger flow events in rail transit stations affect the "ripple reaction" in the process of communication, which is reflected in the fact that the events affect the diffusion in time and space, and also in the fact that the events themselves will trigger other secondary events with different properties and types, namely secondary effects. Large passenger rail transit station events affect the spread of the secondary effect of the process can be described as: the influence of traffic incidents spread is not a single event itself, the influence of simple physical spread on the Internet, but at the same time accompanied by more complex several successively occur or have occurred and parallel secondary reactions, primitive events affect the communication process is secondary reaction by these primitives have constantly repeated to do.

3.5.1. Improved SIR Model of Large Passenger Flow Network Communication

Infectious disease transmission models have good applicability and are widely used in other academic fields. Such as in the research of rail transit passenger flow, traffic congestion can be seen as "virus", by rail transit vehicle arrive station, drive and start as a medium to spread continuously to the rail lines to adjacent the station, the station was "infected", which makes big traffic congestion can be spread in the larger range, transmission, presented by the spread of "point - line - face" process. The stations in normal operation will be affected by the spread of large passenger flow and become the state of large passenger flow events. Meanwhile, the stations with large passenger flow congestion can also be alleviated and gradually become the state of normal operation after reasonable operation management, transportation organization

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and timely adjustment of train operation arrangements. Considering the similarity of the two, we can refer to the model of infectious disease transmission to study the large passenger flow.

In the urban rail transit network, the stations, lines and other facilities together constitute a complete rail transit system. When there is a large passenger flow incident in a rail transit station in the rail transit network, the train will be fully loaded when it stops at the station and departs. When arriving at the downstream station, even after some passengers get off the train, the remaining capacity is still very limited. Only a small number of passengers will be allowed to board the train and subsequent passengers will have to wait for the next train. If the situation lasts for a long time, the passengers in the station will overstock seriously, and there will also be a large passenger flow congestion, which is the "contagion" process of the large passenger flow event.

1) SIR The classical model

SIR (susceptibility - infection - immunity) model belongs to the warehouse model, which divides individuals into three states: susceptibility (S), infection (I), and immunity after recovery (R). Immune status refers to the recovery of immune characteristics from a diseased state or failure to be cured resulting in death, that is, no longer able to touch the susceptible individuals.

If in a common system in a state of susceptible individuals and infection status of individuals in the event of contact, so in the infection state of individuals may be put through a certain probability λ makes its disease virus to susceptible individuals, But there is also a chance that the individual with the disease μ will heal itself to a normal state known as the immune individual.

2) Improved model

In the SIR improved model, According to the operation state of each station, it can be divided into: normal state not affected yet (S); Under the influence of the large passenger flow of this site, the large passenger flow is crowded (I); To return to a normal state after being affected (R). According to the law of infectious disease transmission, the following large passenger flow transmission model can be obtained:

$$\begin{cases} \dfrac{dS}{dt} = -\lambda SI \\ \dfrac{dI}{dt} = \lambda SI - \mu I \\ \dfrac{dR}{dt} = \mu I \end{cases} \tag{1}$$

That is:

$$\begin{cases} \Delta S_{t+1} = -\lambda S_t I \\ \Delta I_{t+1} = \lambda S_t I_t - \mu I_t \\ \Delta R_{t+1} = \mu I_t \end{cases} \tag{2}$$

Where λ represents the propagation rate of large passenger flow congestion, μ represents the dissipation rate of T time congestion, and, S_t I_t R_t respectively represents the number of T stations in S state, I state and R state at time. Mass passenger flow events may occur in transfer stations or intermediate stations in urban rail transit network. When a large passenger flow

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event occurs in the intermediate station, it will gradually spread along this line. When it happens at the transfer station, it can also spread to the other rail lines it intersects. Latest number of stations affected by heavy passenger flow: $N\lambda_N$

Type: N Represents the number of stations adjacent to the station where a large passenger flow event occurs,

λ_N Represents the traffic congestion propagation rate of large passenger flow, Is the number of all stations affected by large passenger flow events:

$$E(-\Delta S) = N\lambda_N - \mu I \tag{3}$$

Calculation: $\Delta I_{t+1}=[N\lambda_{Nt} - \mu_t I_t]I_t - \mu_t I_t$ (4)

$$I_{t+1} = I_t + \Delta I_{t+1} \tag{5}$$

Type: λ_{Nt} Represents the crowded network propagation rate at time T

Ut Represents the dissipation rate of crowding at time T, Because it is difficult to obtain real-time congestion propagation rate and recovery rate, the model SIR of networked congestion propagation is simplified and these two parameters are set as fixed values:

$$\Delta I_{t+1}=[N\lambda_N - \mu I_t]I_t - \mu I_t \tag{6}$$

$$I_{t+1} = I_t + \Delta I_{t+1} \tag{7}$$

According to this model, the influence scope of large passenger flow events can be more accurately grasped, and then more targeted measures can be taken to improve the service level.

4. Analyze the Coping Strategies of Large Passenger Flow Incidents

Based on the large passenger flow analysis of the formation and propagation events, large passenger rail transit station incident coping strategies can be correspondingly from control to flow, improve the transmission capacity, strengthen the passenger flow organization and pay attention to the weak link four directions, and from the big traffic incident prevention, emergency treatment and evaluating later discusses the three levels, big traffic incident when a rail transit station, in order to reduce the impact on the rest of the station, thus avoiding other station passenger flow, can through the following measures:1) Improve the carriage model of the train to increase the carrying capacity of the train.2) Properly organize train operation to shorten the time between train operation and arrival3) Equipped with perfect passenger flow guidance facilities in the station, organize passengers to wait for the bus in an orderly manner and get on and off the passengers to avoid crowding in the station.4) Take temporary measures to guide the passenger flow in a directional way, avoid the collision between the two directions, and improve the transport capacity of the passenger channel in the station.

5. Case Study

Take Nanjing Subway Xinjiekou Station on May Day holiday as an example The May Day holiday puts great pressure on urban rail transit. Xinjiekou subway station as Asia's largest, 24 export, traffic national top three, and in a small long vacation before five organization staff to carry on the theoretical study and field practice, set up emergency response teams, to arrange personnel

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to large passenger flow to support the security work at the same time, strengthen the scheduling, cabin and security of station equipment. Prepared current limiting rod, amplifiers, flashlight, etc to prevent crowded stampede, through technical means and the historical data of xinjiekou to predict and analyze the May Day holiday, in different sites with different number of the staff in order to guide, through the above research and planning the deployment of xinjiekou provide tourists pass in and out of the subway station in the May Day holiday in an orderly way, and if we don't have such a reasonable arrangement and implement the specific planning in advance the May Day holiday to xinjiekou subway station will be ugly, so we must carry on the reasonable analysis of rail transit passenger flow events, make reasonable planning by using data can be collected, Propose preventive measures so that nothing can change.

6. Summarizes

In this study, after the occurrence of large passenger flow incident in rail transit station, all aspects of the evolution process of the whole event were evaluated in detail, so as to continuously learn and improve the ability to deal with large passenger flow incident in rail transit station. A very important aspect of this level is to conduct a detailed investigation and evaluation of the handling process of large passenger flow incidents, make plans, and constantly summarize experience. Compared with natural disasters, accidents, failures, man-made damage and other major emergencies, mass passenger flow events in rail transit stations occur more frequently and become a major type of events that the rail transit system needs to deal with. On the basis of defining the mass passenger flow events in rail transit stations, this paper makes a quantitative analysis of the causes of mass passenger flow events and the propagation and diffusion mechanism of network influence, and probes into the corresponding strategies. Based on the analysis and planning of mass passenger traffic events in rail transit, this paper should be advocated for development. The research also has timeliness and can solve some problems in contemporary society.

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