Research on the Crowd Behavioral Characteristics in Urban Rail Transit

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Abstract

The behavioral characteristics of the crowd are the bases for establishing the crowd behavior models and for drawing up the crowd evacuation plans. Taking the existing researches as basis, according to the mass investigations and data collection on the crowd behavior within the metro sites, and considering with some factors influencing crowd behaviors, the crowd can be divided and analyzed as crowd – group - individual three levels, corresponding to macro – meso - microscopic characteristics of the crowd behavior respectively.

Keywords: Underground rail transit. Crowd behavioral characteristics. Crowd behavior. Crowd evacuation. Influencing factors

1. Introduction

In order to alleviate increasingly prominent traffic pressure, rail transit has gradually become one of the main transportation methods for the urban population, so it also makes the rail transit sites become one of the large population collecting and distributing centers. Therefore, it is very necessary for organization and evacuation of the crowd that making research on the crowd behavioral characteristics in urban rail transit.

With the rapid development of computer technology, computer simulation technology has gradually become the main way for behavior study. Pedestrian behaviors that are the foundation of computer simulation are complex, random and nonlinear, so crowd behaviors study has become the necessary and difficult point in the crowd behavioral research field.

Foreign scholars got the early steps, since 1970s, they had started to study crowd flow characteristics and individual behavior under the disaster environment. The major research methods were direct observation and data statistics. Presently, the studies on theory have tended to unified and nature.

Research results in domestic are relatively scattered. Most domestic studies were quoted the foreign achievements and data. However, crowd behavioral characteristics in our country, such as physical and mental features, cultural background and population density under special situations have profound discrepancy compared with other countries[1], these differences will produce many errors in the procedure that behavior modeling and evacuation simulation.

Taking the research achievements from overseas and domestic as the foundation, considering the specificity of urban rail transit stations, the author summarizes the crowd behavioral characteristics, for providing reference to domestic studies on crowd behavior, and offering bases for modeling crowd behavior and simulating crowd evacuation.

2. Crowd Behavioral Characteristics

The crowd can be divided into three different levels--crowd, group and individual. Crowd consists of two or more than two groups, group is formed by different individuals, and individual is the basic unit of the crowd[2]. The behavioral features of these three different levels can be described as macro-meso-micro characteristics of the crowd respectively. Dividing the crowd into these three levels can describe the different crowd behavioral characteristics under the normal and evacuating status more clearly and more accurately.

2.1 Macroscopic Characteristics

Macroscopic characteristics of the crowd are defined as behavioral features performed by a mass pedestrian in some certain time and space condition, mainly including walking speed, density and flow.

a. Walking speed

Walking speed is a velocity vector referring to theory, but we just talk about its value. From macro-properties, walking speed is talked as the average speed of large numbers of walking pedestrians; generally take m/s or m/min as units.

Walking speed will be influenced by some individual features and environmental factors. As shown in Table 1, what the survey data from different countries, the average free walking speed of the crowd under the normal status located 1.20m/s~1.40m/s and variance's value located 0.20m/s~0.30m/s. According to the statistics data of the crowd walking speed in urban rail transit site passageways, the speed is a little bit higher than that in common environment, under the free walking condition, the highest average walking speed can reach 1.61m/s [3].

Table 1 Average free walking speed of pedestrians in normal status

Researcher(person/school)	Speed (m/s)	Place/Type	Variance (m/s)	Rail Transit
Beijing Jiaotong University[3]	1.61	Data in urban trial transit passageways	------	Yes
Fruin [4]	1.35	Average value of 1,000 people in New York	0.15	No
Tregenza [5]	1.31	Britain	0.30	No
Henderson [6]	1.44	Australia	0.23	No
Tanariboon [7]	1.23	Singapore	------	No
Lam [8]	1.19	Hong Kong	0.26	No
Chen Ran [9]	1.24	Shanghai	------	No

b. Flow

Flow is defined as the number of pedestrians through one certain point per unit time, it takes p/m s or p/m min as units. In rail transit stations, the crowd flow is a vector, its rate is determined by the crowd walking speed and the total quantity of pedestrians through one certain point; its direction is expressed by a three dimensional vector, $\vec{q} = (q_x, q_y, q_z)$. q_x, q_y, q_z represents the flow of lateral, longitudinal, vertical direction respectively. In the underground rail transit sites, q_z is used to represent the crowd flow passing through the paths which connect overground with underground space, the value of q_z is zero when the crowd move in the flat passageways only.

c. Density

Density refers to the average number of pedestrians in unit area, and it takes p/m2 as the units. We generally take the relation density-speed and density-flow as the main objects for studying.

(1) Density-Speed

As shown in figure 1, with density increasing, pedestrian speed takes linear downward trend.
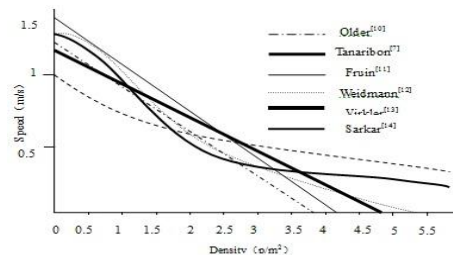

Fig. 1 Some research results on density-speed relation

(2) Density-Flow

The relation between density and flow essentially obeys quadratic function, some research results as shown in figure 2. Although these conclusions are somewhat different, but generally speaking, as density increases, the flow represents the trend that increases firstly and then decreases, the maximum flow point appears in the density of 1.8 p/m 2 to 2.2 p/m2 .
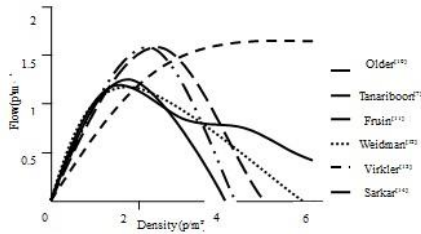

Fig. 2 Some research results on density-flow relation

2.2 Mesoscopic Characteristics

Mesoscopic characteristics take the behavioral features of groups as the object of study. Group is made up of two or more than two individuals who have same walking purposes or actions. The individuals in one group show basically same behaviors in the certain time and space range, but not necessarily consistent between groups.

The primary study of meso-characteristics is solving problems how to group the crowd. There are two main classifications--grouping as physiological features and grouping as behavioral purposes.

a. Grouping as physiological features

(1) Gender

As statistical data shows, the average walking speed of male is 10.9% faster than female. According to the study by Weidmann [12], in the flat passageways, the average walking speed of adult men is 1.41m/s, while that of adult women is 1.27m/s. In a panic condition, actions taking by different gender group are different too. When in an emergency, men gen-erally take direct actions, while most women usually transfer information or wait for rescue.

(2) Age

As shown in statistical data of observation, the walking speed of pedestrian whose age from 20 to 60 is significantly higher than whose age above 60. Some researchers suggest that, in an emergency situation, the elder group has more sensible behaviors comparing with younger one.

(3) Physical condition

Physical problems which can influence pedestrian behaviors include following types: physical disabilities, hearing impairment, visual impairment, etc. As far as the evacuation capacity of rail transit sites, the action ability of some groups with physical questions is a little weak, and its average walking speed is lower than other normal one, its identification ability for dangerous signals is feeble, and it also lack of the capacity for judging evacuation information.

(4) Race

As statistical data of pedestrian walking speed from most parts of the world shows, the average walking speed of Europeans and Americans is higher than that of Asians; he maximum distribution of flow in Asian cities locates from1.48 p/m s to 1.53 p/m s , while in European and American cities, the maximum distribution of flow is just between 1.0 p/m s and 1.29 p/m s.

b. Grouping as walking purposes

According to pedestrian walking purposes, the crowd can be grouped into three kinds of group: inbound-outbound-transferring group. The biggest differences between these groups are walking routes. In different sites, the walking speed and density of each group is somewhat different. Comparing with the pedestrians of inbound group and transferring group, those in outbound group will linger in the station for a shorter time.

2.3 Microscopic Characteristics

Microscopic characteristics can be defined as the features of individual expressing under various situations. It not only depends on individual oneself, but also on the relation between individuals, and that between individual and environment.

a. Herd Behavior

Herd behavior describes how individuals in a group can act together without planned direction. So it also can be called "following" behavior. By field observation, author found that the phenomenon of herd behavior in rail transit stations is especially obvious. When the metro arrives at the stop, eliminating some man-made factors such as acquainting the space structure of metro station, and other special circumstances such as missing stops, there are more than 60% pedestrians will follow the crowd without planned direction. Herd behavior has some features as following [15]: The first one is blindness. The second one is unconsciousness. The third one is spontaneity. Herd behavior is ubiquities in the real life. The higher the spatial crowd density is, and the more evident the phenomenon of herd behavior will be. In crowd panic states, herd behavior will exacerbate. Herd behavior will cause a series of safety problems [16]: First, herd behavior will cause the big crowd form a "vault" at the exit, which will affect the efficiency of crowd evacuation; Second, pedestrians will select exits following the crowd, which will lead to some other evacuating exits be ignored, and the evacuation time will be extended; Third, crowd density will increase rapidly which may cause congestion.

b. Collision Avoidance Behavior

Pedestrian will keep a certain distance between with walls, obstacles and other people, on instinct, when walking in the metro stations. This phenomenon in called collision avoidance behavior and this certain distance can be called "collision distance". The value of collision distance is related to the degree of freedom of pedestrian oneself and how was the spatial arrangement. Some research results as shown in table 2.

Table 2 Collision distance between pedestrian and various objects

Object	Distance (cm)	Scholar
Concrete Wall	30-45	CROW[17]
	45	De Neufville&Grillot[18]
	40	Van Soeren[19]
	25	Weidmann[12]
Obstacle	40	Van Soeren[19]
	10	Weidmann[12]
Reverse Pedestrian Flow	60	De Neufville&Grillot[18]
Pedestrian*	27.5	Knoflacher[20]
Platform Edge	80	Van Soeren[19]

Pedestrian*---Collision distance between pedestrians can be affected by many factors: (1) Regional culture. The collision distance of Asians is relatively smaller than that of Europeans and Americans[21]. (2) Walking directions. Avoiding conflicting with others, the collision distance between pedestrians walking in reverse direction is longer than that walking in same direction. (3) Density. In a crowded environment, collision distance between pedestrians will decrease therewith.

c. Neighborhood Effect Behavior

Neighborhood effect was put forward for independent effect [22].Independent effect can be defined as an effect that all the factors influencing pedestrian behaviors in the space are independent with each other, while neighborhood effect behavior is a kind of individual behavior that people will consider comprehensively all the factors that can take impact on pedestrian behaviors, when they need to make a choice to do something, and then make judgment about how many available directions for walking in the space, which one is optimal to reach the destination, and what is the maximum feasible dis-

tance, expected rate and available steering angles, etc. ,and finally determined the direction and rate of speed for walking, for avoiding conflicting with other people and obstacles.

d. Special Behavior preference

Individual preference is the individual behavior that individuals prefer making decisions consisting with their own penchant. Some typical pedestrian special behavior preference will be discussed as following:

Preference of the shortest path:

Most of the pedestrian behaviors carrying with an explicit purpose, all of them hope to choose the optimal paths to the destination. The optimal path talked here is the shortest path connecting starting point and destination of geometrical concept. However, through actual observing, most pedestrians usually prefer choosing the time optimal path which costs minimum duration to selecting the distance optimal path which has the shortest distance [23]. In the condition of low density and knowing spatial arrangement well, pedestrian can walk at a free speed, the time optimal path can be equal to the distance optimal path.

Preference of automatic facilities:

In the underground rail transit sites, for the connecting facilities in vertical space, pedestrians prefer taking elevators or escalators to walking through stairs. By actual observing, most pedestrians rather slowing down their walking speed and waiting for elevators or escalators, than choosing stairs; few of people will give up taking automatic facilities because the speed of taking escalators or elevators is much lower than their expected speed.

e. Clustering Behavior

Clustering behavior is a kind of phenomenon under the situation of crowd evacuating, it also can be called "small community behavior". In the program of crowd evacuation, the evacuees trend to together with their family, friends and other groups sharing the similar purpose before evacuating, and then act in company. From perspective of psychology and praxeology, the crowd can be split into four categories: family cluster, work cluster, space-time cluster and benefit cluster[15]. Hereinto, space-time cluster exists in the particular condition of time and space, which belongs to small community forming in a short period of time in order to achieve a sort of goal. Most clusters forming in the process of crowd evacuation are space-time clusters.

3. Influencing Factors

Considering the spatial particularity of the rail transit, following gives out some main factors that can influence the crowd behaviors in rail transit sites.

3.1 Space Binding

Most of the underground rail transit sites are relatively airtight environment, so the crowd behaviors are different from other conditions. For instance, when people walking in airtight space, their acquisition of information is limited, the pressure getting from space is higher, so the walking speed of pedestrians will be higher than usual.

3.2 Structural Complexity

Along with the continuous development of urban rail transit, the spatial structures of underground sites have become more and more complex. It not only contain various service and walking facilities, and also have some connections with shopping malls and entertainment centers, which make spatial structure of metro sites complicated. Meanwhile, because of the neighborhood effect, more factors should be considered before making decisions in the structural complexity sites.

3.3 Dense Population

As the main transportation for urban citizens, rail transit has dense population. Due to the feature that spatial non-expanding of stations in a short time, the higher the crowd density is, the greater probability the collision and friction between pedestrians is.

3.4 Complexity of Flow Directions

When there only exists unidirectional crowd flow, the collision distance between pedestrians, pedestrian and obstacles are constant and short, so the walking speed can keep on a certain expected value, and will be higher than that of multidirectional crowd flow; under the same spatial conditions, the collision distance between pedestrians will obviously get longer when there exist bidirectional or multidirectional crowd flow, and the randomness of walking routes choosing will heighten, as well the speed will go down and the clash between different directions flow will be obvious.

3.5 Imbalance of Crowd Flow

Different metro sites have different daily traffic, which cause crowd flow imbalanced, for example, the site with in and out functions only has relatively lower crowd flow and density, pedestrians can walk at a high speed. While the site owning transfer besides in and out functions has relatively higher crowd flow. At different time, the crowd flow is different in the same site. When subway getting in the stop, the crowd flow will increase sharply, and decrease gradually for a while.

4. Conclusions and Prospections

Individual is the minimum unit of the crowd, several individuals who have some characteristics in common constitute a group. The behaviors between different groups are various, and several groups form a crowd. When studying on crowd behaviors, we can do researches on the crowd behaviors from the macro-meso-micro perspective respectively, according to the division of the crowd, so as to conduct the crowd behavior models building and the computer simulation parameters setting.

The rail transit in our country has just developed for decades, the studies on crowd behaviors still at the imitate stage, most parameters of the crowd behaviors still refer to foreign data. However, the experiment data demonstrates that, there are some certain differences in behaviors between eastern and western, which make the current behavior model not accurate enough. So we still need more experimental observations, taking the actual condition of our country and rail transit condition as basis, to get the goal of setting parameters more scientifically and reasonably, preventing disasters happening more efficiently, and reducing casualties and economic losses caused by events more effectively.

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6. Reference

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