Analysis of Pedestrian Walking Microscopic Characteristics in Urban Rail Transit Station Different Types Passageway

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Abstract: In order to study the microscopic characteristics of pedestrians in different types of traffic in urban rail transit stations, data on the field were collected and used to compare and analyze the basic parameters of pedestrian walking in various aspects, including different types of passageways in urban rail transit stations, one-way passageway and two-way passageway, passageway to and from the station and transfer passageway, as well as upper and lower slope passageway and horizontal passageway. The following conclusion is drawn: pedestrian walking speed in commuter stations is the highest, and coming next are pedestrians in transfer hub stations and residential stations, while pedestrians walk the slowest in commercial center stations and sightseeing stations; Pedestrian walking speed in one-way passageway is higher than that in two-way passageway, and the pedestrian conflict mainly affects the stride parameters; Pedestrian walking speed in transfer passageway is lower than that in passageway to and from the station; Inbound and outbound pedestrians differ in walking characters depending on their travel purposes and properties of rail stations; In a passageway with slope measured at 15%, every walking parameters of pedestrians in uphill passageway is lower than that of pedestrians in horizontal passageway, the walking speed, specifically, is reduced by 13.74%; Compared to pedestrians in horizontal passageway, pedestrians in downhill passageway has higher walking frequency and smaller stride. The conclusion can provide the basic parameters for micro-traffic simulation, as well as reference data to implement the urban rail transit passenger station design, passenger flow organization, facility layout optimization and facilities evaluation. The theory of pedestrian traffic is also enriched.

1. Introduction
Passageway is a way for passengers to enter or leave station or to transfer to another line. It's a buffer zone for connecting different function facilities in station. It is also a kind of non-delay walking facilities, and has a strong guidance. According to the existence of opposite pedestrian flow, it can be divided into one-way passageway and two-way passageway. According different functions in the station, it can be divided into inbound passageway, outbound passageway and transfer passageway. According to slope or not, it can be divided into slope passageway and horizontal passageway. Pedestrian characteristics in different type stations are different. Pedestrian characteristics vary significantly at different stations in the same station. Even in the same station, pedestrian walking characteristics have obvious difference in different types of passageway. In order to study pedestrian walking characteristics in different types passageway, understand the pedestrian in the features of different types of channel, to provide basic basis for the station facilities design and evaluation, station passenger flow organization optimization, pedestrian simulation, this paper makes statistics and analysis on the pedestrian traffic micro characteristics of different types passageway, which is based on
field investigation of typical subway station in Guangzhou metro.

2. Literature Review

Pedestrian traffic theory research began in the 1950s, the scholars of different countries have done a lot of research on pedestrian traffic. These studies involving pedestrian traffic micro characteristics and macro characteristics in different venues and facilities, which traffic characteristics of pedestrians crossing is the most studied. Moreover plaza, shopping malls, schools and stations is also the important research sites concerned by scholars. With the rapid development of urban rail transit, more and more scholars have studied pedestrian traffic characteristics of urban rail transit stations in recent years.

Macro characteristics: the researchers fit the relationship of traffic flow parameters such as speed, density, flow and pedestrian space to study pedestrian traffic characteristics. Lam et al. (1995) has fitted the relationship between speed, density, flow and pedestrian space by investigating the pedestrian characteristics of the metro station in Hong Kong [2]. Li (2007) counted the pedestrian traffic data in Beijing metro station by using the semi-automatic data collecting system, and summarized pedestrian macro characteristics such as speed, flow, density, space and crowd [3]. Ye et al. (2008) studied pedestrian flow characteristics for one-way passageway, two-way passageway, upstairs facility and downstairs facility in metro stations of Shanghai and developed the flow-density-speed relationship [4]. Li (2008) has fitted the pedestrian speed-density relationship between upstairs, downstairs, inbound passage, outbound passage, one-way hub passage and two-way hub passage through comparing pedestrian traffic characteristics at different walking facilities in urban rail transit [5]. Chen et al. (2010) discussed the flow-density-speed relationship for horizontal passageway, upstairs, downstairs and two-way stairway walking facilities [6]. Zhang et al. (2011) studied the pedestrian traffic characteristics of transfer passageway in transfer station [7].

Micro characteristics: the micro behavior and micro walking parameters of pedestrians in the station are used to analyze. Li (2007) studied the micro behavior of passengers in the hub from six aspects, including facility behavior, flow direction, destination behavior, congestion behavior, time interval behavior and safe evacuation behavior. The walking characteristics of male and female pedestrians in the passage with or without slope were compared. Meanwhile the average speed of upper and lower stair and passage are compared as well [2]. Xu (2008) and Cao (2009) analyzed the gender and slope influence on passengers walking speed, stride length and stride frequency by using statistics [7-8]. Chang (2010) studied the pedestrian micro behavior characteristics of different facilities in Beijing metro station, and analyzed the correlation between pedestrian speed of the passageway and gender, flow rate, and pedestrian density in the front [9]. Hu et al. (2011) investigated basin and the congestion zone walking speed, stride length and stride frequency of the metro station in shenzhen [10]. Luo et al. (2012) analyzed the composition of the subway station population, and summed up the speed respectively on the flat ground upstairs and downstairs under the influence such as age, gender, carrying luggage, companion situation [11]. Wang (2013) analyzed the influencing factors of pedestrian traffic in urban rail transit stations, and studied the micro-traffic characteristics of pedestrians at passage facilities and stairway facilities under different influencing factors and the characteristic parameters of pedestrian traffic relationship by field investigation and data collection of Nanjing subway station [12]. Liu et al. (2014) fitted the mathematical relationship between pedestrian stride, speed, frequency and personal space in the passage [13]. Zhe Zhao et al. (2016) analyzed the movement speed of pedestrians under influencing factors such as gender, age, baggage, shoes and companion by observing the pedestrian movement at three typical shopping centers station in Guangzhou Metro Line 1 [14].

Reviewing pedestrian characteristics research results of urban rail transit at home and abroad, pedestrian traffic characteristics being analyzed from the perspective of different facilities is of the majority. However, due to the complexity of pedestrian traffic, there is big difference in pedestrian traffic characteristics between different attribute facilities or different functions facilities. Then this
paper will investigate microscopic characteristics of pedestrian traffic at different types of passageway, to improve the pedestrian traffic theory.

3. Data Collection and Parameter Extraction
The research method of this paper is that based on field data acquisition, using video analysis software and statistical analysis software, processing the collected data, then the influence on pedestrian micro behavior characteristics of urban rail transit station passageway is analyzed based on the statistical results.

3.1 Data Collection Method
There are two main methods for data collection: manual observation and video acquisition. Firstly, the location of the camera is determined by artificial observation, and the physical properties of the study area in the passageway are measured, to obtain statistical data of microscopic characteristic parameters (such as length, width, slope, etc.). Then the camera is set up for video capture according to the determined position.

3.2 Observation Time and Sites
In order to collect pedestrian data of passageway at different types station passages and of passageway with sloping, the data collection sites are selected in Zhujiang New Town Station, Kecun Station, Dongxiaonan Station, Guangzhou Railway Station, Tiyu Xilu Station, Canton Tower station and Haizhu Square Station of Guangzhou Metro. Taking into account the travel characteristics of the Guangzhou residents, with Zhujiang New Town Station belonging to the typical commuter station connected to the Guangzhou Municipal Government Center, a large number of office building around the station, time to collect data was selected in a working day of 17:00 ~ 19:00. With Kecun Station being a transfer station, research time was selected from a working day of 17:00 ~ 19:00 and a weekend 17:00 ~ 19:00. Dongxiaonan Station belonging to a living residential station, the data collected time was selected in a working day of 18:00 ~ 20:00. With Guangzhou Railway Station being a large integrated transport hub, research time was a weekend 14:00 ~ 16:00; With Tiyu Xilu Station being a large commercial center station, research time was a weekend 17:00 ~ 19:00; Canton Tower station belonging a tourist sightseeing station, research time was a weekend 10:00 ~ 12:00; Because Haizhu Square Station is a ordinary transfer station, and it has a section of slope in the transfer passageway, the research time was selected in a Weekday 17:00 ~ 19:00.

3.3 Data Collation and Analysis
There are three micro basic characteristic parameters of pedestrian traffic being analyzed: walking speed, stride length and stride frequency.

Walking speed is the distance that pedestrians move towards the specified direction within unit time, expressed in V. The unit is meter per second.

\[ V = \frac{L}{T} \quad (m/s) \]

Stride length is a step length of pedestrian walking, expressed in \( B_L \). The unit is meter.

\[ B_L = \frac{L}{D(m)} \]

Stride frequency is steps frequency of pedestrians, that is the times of pedestrian both heel to the ground in unit time, expressed in \( B_f \). The unit is step per second.

\[ B_f = \frac{D}{T(\text{step/s})} \]

Where \( L \) is observation distance, expressed as meter. \( T \) is the time for pedestrians to pass through the observation distance, expressed as second. \( D \) is the number of steps for pedestrians walk through observation distance, expressed as step.

In order to obtain accurate pedestrian micro parameters, the collected video is broken down into 25 frames per second image by using Corel VideoStudio 12 software. In order to guarantee the accuracy
of statistical data achieving 0.04s, video is observed and analyzed frame by frame. Through video analysis can obtain the time for pedestrians to pass through the observation distance T and the number of steps for pedestrians walk through observation distance D. Thus the observed walking speed, stride length and stride frequency are obtained.

4. Comparison and analysis of pedestrian basic parameters

4.1 Passageway in Different Types Stations
According to the geographical location is different, urban rail transit station can be divided into office commuter station, commercial center station, living station, ordinary transfer station, tourist station and integrated hub station. Because the main passengers have different travel purposes at different types of stations, there are great differences in passenger traffic characteristics. It can be seen from Table 1 that commuter station pedestrian travel the most hasty with the maximum average walking speed. While pedestrians in commercial center station and tourist sightseeing station have the smallest average speed because of not in a hurry or traveling with companion. The pedestrian average speed of ordinary transfer station, integrated hub station and living residential station is mediate because all kinds of people are existent. The difference of pedestrian stride length characteristics between different types of stations is not obvious, compared with speed. But stride length of pedestrian in commuter station is the largest, followed by pedestrian in living residential station. Stride length of transfer station pedestrian is less than that of the living residential station, may due to high pedestrian density of transfer hub station, which the stride length are limited. While the average stride length of leisure station pedestrian is still the smallest. The average walking frequency of the hub station is the largest, and the office commutes station is slightly less than the hub station. The average pedestrian frequency of the commercial center station, the tourist station and the living station is the smallest.

Table 1 Basic Walking Parameters Statistics of Passageway Pedestrian at Different Type of Stations

| Grouping                   | Office Commuter Station | Living Residential Station | Ordinary Transfer Station | Integrated Hub Station | Commercial Center Station |
|----------------------------|-------------------------|-----------------------------|---------------------------|-------------------------|---------------------------|
| Statistic                  | Walking speed (m/s)     | Stride length (m)           | Stride frequency (step/s) | Walking Speed (m/s)    | Stride Length (m)         | Stride Frequency (step/s) |
| Mean                      | 1.38                    | 0.72                        | 1.90                      | 1.28                    | 0.67                      | 1.92                      |
| Minimum                   | 0.86                    | 0.54                        | 1.36                      | 1.02                    | 0.38                      | 1.24                      |
| Maximum                   | 2.18                    | 1.01                        | 3.31                      | 3.46                    | 1.02                      | 3.65                      |
| Standard Deviation        | 0.0170                  | 0.0062                      | 0.0182                    | 0.0114                  | 0.0059                    | 0.0120                    |
| Statistic                  | Walking speed (m/s)     | Stride length (m)           | Stride frequency (step/s) | Walking Speed (m/s)    | Stride Length (m)         | Stride Frequency (step/s) |
| Mean                      | 1.26                    | 0.70                        | 1.79                      | 1.28                    | 0.67                      | 1.93                      |
| Minimum                   | 1.02                    | 0.60                        | 1.61                      | 0.78                    | 0.38                      | 1.22                      |
| Maximum                   | 1.89                    | 0.95                        | 2.00                      | 2.53                    | 1.02                      | 3.02                      |
| Standard Deviation        | 0.0421                  | 0.0193                      | 0.0246                    | 0.0130                  | 0.0059                    | 0.0128                    |
| Statistic                  | Walking speed (m/s)     | Stride length (m)           | Stride frequency (step/s) | Walking Speed (m/s)    | Stride Length (m)         | Stride Frequency (step/s) |
| Mean                      | 1.28                    | 0.67                        | 1.92                      | 1.28                    | 0.67                      | 1.93                      |
| Minimum                   | 0.78                    | 0.38                        | 1.24                      | 0.77                    | 0.38                      | 1.22                      |
| Maximum                   | 2.53                    | 1.02                        | 3.02                      | 3.46                    | 0.97                      | 3.65                      |
| Standard Deviation        | 0.0130                  | 0.0059                      | 0.0128                    | 0.0114                  | 0.0040                    | 0.0120                    |
4.2 One-way and Two-way Passageway
With the difference of pedestrian walking characteristics at different types station has been discussed in front, pedestrian walking characteristics data of one-way and two-way passages in the same station was used, to better analyze the the impact of pedestrian walking characteristics in the presence of opposite pedestrian flow. Comparing results is shown in Table 2. Average speed and average stride length of one-way passages is larger than that of two-way. Average frequency of two-way passages is slightly larger than the one-way passageway. It indicate the presence of opposite pedestrian flow has the great impact on pedestrian walking characteristics. Because of conflict by opposite pedestrian flow, stride length of two-way passageway pedestrian are limited, causing the speed slow down. But some people who are in a hurry will speed up their pace by making a detour. So stride frequency of two-way passageway is slightly larger than the one-way passageway.

Table 2 Pedestrian Basic Parameters Statistics of One-Way and Two-Way Passageway at Guangzhou Railway Station

| Grouping                  | Statistic              | Mean   | Minimum | Maximum | Standard Deviation |
|---------------------------|------------------------|--------|---------|---------|--------------------|
| One-way passageway        | Walking Speed (m/s)    | 1.31   | 0.99    | 3.42    | 0.0285             |
|                           | Stride Length (m)      | 0.68   | 0.54    | 0.96    | 0.0080             |
|                           | Stride Frequency (step/s) | 1.92   | 1.33    | 3.57    | 0.0260             |

| Grouping                  | Statistic              | Mean   | Minimum | Maximum | Standard Deviation |
|---------------------------|------------------------|--------|---------|---------|--------------------|
| Living Residential Station| Walking Speed (m/s)    | 1.25   | 0.77    | 1.91    | 0.0258             |
|                           | Stride Length (m)      | 0.65   | 0.39    | 0.88    | 0.0117             |
|                           | Stride Frequency (step/s) | 1.94   | 1.22    | 3.65    | 0.0346             |

4.3 Inbound, Outbound and Transfer Passageway
To compare pedestrian walking characteristics between inbound, outbound and transfer passage, the statistics of different passages in the same station are used. The statistics are shown in Table 3. Comparison of various types of pedestrian, average speed of outbound passage pedestrian is the fastest, followed by the outbound passage, the slowest is transfer passage. There is not much difference between all kinds of pedestrians. The pedestrian stride frequency of the transfer passageway is significantly smaller than that of passageway to and from the station. When comparing inbound and outbound passage, it is not sufficient to only compare the data of this station. Because Guangzhou railway station is the integrated hub station, the outbound passengers may be able to speed up the pace to catch a train. Therefore, the data collected from each station is summarized in Table 4. It can be found that the pedestrian walking characteristics of the transfer passageway are almost unchanged. This shows that the statistical results in Table 3 are persuasive. While comparing with the result of
Table 3, there are slight differences in pedestrian walking characteristics of inbound and outbound passageways. Statistical summary of average pedestrian speed in inbound and outbound passageway is greater than that in transfer passageway. It indicates that the pedestrian characteristics of inbound and outbound passageway are related to the nature of the station as well. As pedestrian arriving in the transfer passages is impulsive, the number of pedestrian increases abruptly with arrival of a train and the number of pedestrian in the passage is drastically reduced or even to zero after a wave of pedestrian getting through. Because the phenomenon is periodicity and pedestrian density is relatively large due to centrally arriving, pedestrian speed will be relatively small. So pedestrian walking speed in transfer passageway is lower than that in passageway to and from the station.

Table 3 Pedestrian walking basic parameters statistics of inbound, outbound and transfer passageway in Guangzhou Railway Station

| Grouping          | Inbound            | Transfer          | Outbound         |
|-------------------|--------------------|-------------------|------------------|
| Walking Speed (m/s) | 1.28 (0.86 - 1.91) | 1.24 (0.99 - 1.57) | 1.32 (0.77 - 3.42) |
| Stride Length (m)  | 0.66 (0.39 - 0.88) | 0.66 (0.54 - 0.81) | 0.68 (0.47 - 0.96) |
| Stride Frequency (step/s) | 1.94 (1.55 - 3.65) | 1.88 (1.33 - 2.28) | 1.94 (1.22 - 3.57) |

Table 4 Statistical summary of pedestrian basic walking parameter at inbound, outbound and transfer passageway

| Grouping          | Inbound            | Transfer          | Outbound         |
|-------------------|--------------------|-------------------|------------------|
| Walking Speed (m/s) | 1.32 (0.85 - 2.18) | 1.24 (0.73 - 2.53) | 1.30 (0.77 - 3.46) |
| Stride Length (m)  | 0.69 (0.38 - 1.01) | 0.66 (0.38 - 1.02) | 0.67 (0.46 - 0.97) |
| Stride Frequency (step/s) | 1.91 (1.36 - 3.65) | 1.88 (1.13 - 3.02) | 1.92 (1.22 - 3.57) |
4.4 Uphill, Downhill and Horizontal Passageway

In order to discuss the effect of slope on pedestrian walking parameters, uphill, downhill and horizontal passage data of this survey are obtained from the transfer passage of Haizhu Square Station. Among them, the gradient of the sloping passage is about 15%. The statistical results of pedestrian walking parameters are shown in table 5. Pedestrian walking speed of horizontal and downhill passage is basically the same, while data of uphill passage pedestrian is 13.74% less than that of horizontal passage. This is consistent with Fruin's research findings that pedestrian walking speed decelerated about 10 percent when walking on a ramp with 10% of the slope [15]. The pedestrian stride of horizontal passageway is the biggest, and the uphill passageway is still the smallest. However, the pedestrian stride of downhill passageway is much smaller than the horizontal ones. When comparing the frequency, downhill passage pedestrian walking frequency is largest, followed by horizontal passage, uphill passage is smallest. In the case of 15% slope, the uphill pedestrian needs to overcome the gravity. The walking parameters are much smaller than the horizontal passage. While the downhill passage pedestrians will accelerate the pace due to gravity acceleration. But speed will be slow down due to the instinct, which is similar to the car running on the slope that the majority will brake. So stride length will be reduced.

| Grouping  | Walking Speed (m/s) | Stride Length (m) | Stride Frequency (step/s) |
|-----------|---------------------|-------------------|--------------------------|
| Uphill    | Mean 1.13, Minimum 0.81, Maximum 1.46, Standard Deviation 0.0537 | Mean 0.64, Minimum 0.51, Maximum 0.82, Standard Deviation 0.0284 | Mean 1.76, Minimum 1.21, Maximum 2.08, Standard Deviation 0.0695 |
| Grouping  | Walking Speed (m/s) | Stride Length (m) | Stride Frequency (step/s) |
| Horizontal| Mean 1.31, Minimum 1.07, Maximum 1.82, Standard Deviation 0.4190 | Mean 0.68, Minimum 0.49, Maximum 0.87, Standard Deviation 0.0220 | Mean 1.94, Minimum 1.67, Maximum 2.50, Standard Deviation 0.0395 |
| Grouping  | Walking Speed (m/s) | Stride Length (m) | Stride Frequency (step/s) |
| Downhill  | Mean 1.31, Minimum 1.05, Maximum 1.71, Standard Deviation 0.0390 | Mean 0.65, Minimum 0.51, Maximum 0.95, Standard Deviation 0.0182 | Mean 2.01, Minimum 1.63, Maximum 2.34, Standard Deviation 0.0381 |

5. Conclusion

Based on field survey data, various types of passageways pedestrian walking basic parameters are compared, including different types of passageways in urban rail transit stations, one-way passageway and two-way passageway, passageway to and from the station and transfer passageway, as well as upper and lower slope passageway and horizontal passageway. And the impact on the factors of the walking characteristics is analyzed. The following conclusions are drawn:

1) Comparing passageway in different types of stations, pedestrian walking speed in commuter stations is the highest. Coming next are pedestrians in transfer hub stations and residential stations, while pedestrians walk the slowest in commercial center stations and sightseeing stations what are leisure-oriented stations.

2) Pedestrian walking speed in one-way passageway is higher than that in two-way passageway; the pedestrian conflict mainly affects the stride parameters.

3) When comparing the inbound and outbound passages and the transfer passages, pedestrian speed of transfer passages is the lowest because of concentrated arrival of the passenger. Inbound and
outbound passage pedestrians are different in walking characters depending on their travel purposes and properties of rail stations. Their walking speed is about 1.3m/s.

(4) In a passageway with slope measured at 15%, every walking parameters of pedestrians in uphill passageway is lower than that of pedestrians in horizontal passageway, the walking speed, specifically, is reduced by 13.74%; Compared to pedestrians in horizontal passageway, pedestrians in downhill passageway has higher walking frequency and smaller stride.

The conclusion can provide basic parameters for microscopic traffic simulation. It also can provide reference data for the design of urban rail transit station, passenger flow organization, pedestrian facilities layout optimization and evaluation facilities, by combing with the nature of the station, the characteristics of passenger flow and the pedestrian traffic flow relationship. It help to improve the pedestrian traffic theory.

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