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Passenger Distribution Regulation of Rail Transit Platform in Standard Station Environment

Shijie Zhang [1, a], Haihang Li [2, b], Hao Sun [3, c]

[1] HEIBEI VOCATIONAL COLLEGE OF RAIL TRANSPORTATION, China

[2] HengShui Ministry of Transport, China

[3] China Transport Telecommunications & Information Center, China

[a] 403014831@qq.com, [b] 516422770@qq.com, [c] 996512997@qq.com

Abstract. Based on the analysis of the construction characteristics and passenger behavior characteristics of the standard station platform of rail transit, combined with the actual data, under the environment of the standard station, the distribution law of the platform passengers is studied. Through the change of different flow, the influence of the change on the overall distribution is studied, which provides a new idea and method for the study of the passenger distribution on the standard platform of rail transit.

Keywords: Rail Transit; Standard Station; Passenger Distribution; Normal Distribution.

1. Introduction

As an important platform connecting passengers and rail vehicles, rail transit platforms play an extremely important role in passenger distribution, pedestrian flow organization, and station operation plans. Rail transit platforms are areas with high passenger density and the most complex flow. In a standard station environment, a unified platform structure is more conducive to the overall management of the entire line's operational organization plan. Therefore, studying the passenger distribution model of rail transit platforms in standard station environments is of great significance.

2. Rail Transit Standard Station

2.1. Overview of Standard Stations

A rail transit standard station is a standardized design, construction, and operation system that controls the size of the station, public area layout, public restroom layout, and the size of some equipment management rooms. Through standardized processes, the aim is to accelerate the design progress, improve design quality, and reduce station engineering quantity for rail transit platforms.

2.2. Platform Layout

Platform is the space that accommodates passengers waiting for trains, and all activities of passengers are affected by the size of the platform. The division of waiting areas and the determination of their capacity must be carried out in the existing station layout environment. Through statistics on the design of various standard stations across the country, various layout plans are almost unified. The layout of standard station platforms generally adopts the design of island platforms to ensure smoother passenger flow organization, clear guidance, convenient management, fewer station equipment, and lower operating costs. The platform width should be calculated and determined based on the long-term design passenger flow of each station, and should be checked based on the peak hour passenger flow during the control period. Consider designing a building escalator with one staircase and one escalator arranged at one end, and two escalators arranged at the same time at the other end. A sampling survey was conducted on the platform width of national subway standard stations, as shown in Table 1. This study used a double column station with a platform width of 12m.

Table 1. Comparison of station forms across the country

Metro Line	Platform form	Platform layout	Number of pillars	Column form
Hefei Metro Line 1	Standard station	Island style	11	Single column
Taiyuan Metro Line 2	Standard station	Island style	13	Double column
Chongqing Metro Line 10	Standard station	Island style	12	Double column
Beijing Line 6 Phase II	Standard station	Island style	12	Double column
Tianjin Metro Line 7	Standard station	Island style	12	Double column
Shijiazhuang Metro Lines 1	Standard station	Island style	12	Double column

The layout of the escalator should be determined based on the maximum passing service capacity of various traffic service facilities in the station. In this study, a 1.5m vertical elevator and L-shaped staircase were used in the middle, with one end arranged as an up and down escalator and the other end arranged as an up escalator and a 2.5m staircase, as shown in Figure 1.

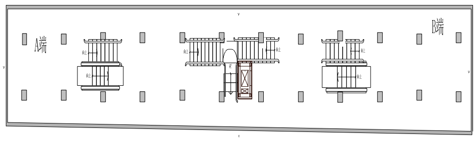


Fig 1. Escalator layout in public area

3. Analysis of Passenger Characteristics

Through the observation of passenger behavior at a certain subway platform, this article believes that there are several important factors that affect the selection and overall distribution of waiting positions.

(1) Total number of passengers on the platform (Q)As the most important influencing factor, the number of passengers at the entrance is directly proportional to the number of waiting passengers at each waiting location. The larger the passenger flow, the more waiting passengers there are at each waiting location.

(2) The distance from the waiting position to the staircase (d)The distance factor is an important factor that affects passengers' choice of waiting location. Generally, passengers are willing to choose a location closer to themselves to wait, so island platforms that enter and exit at both ends often exhibit a bimodal distribution of passengers. The measurement method for the distance between the waiting position and the entrance is based on the linear distance from the center point of the connection between the entrance staircase and the platform to the center point of the corresponding boarding and landing area of each door at the center line of the platform.

4. Passenger Distribution Patterns under Different Influencing Factors

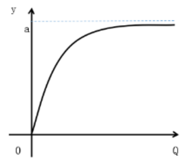
In the modeling process of this article, the period from the departure of the train to the arrival of the next train is regarded as a waiting period, and the number of passengers arriving at each platform entrance during the period is counted. The flow Q refers to the total number of passengers at the entrance, the distance d refers to the waiting position (i.e. the position of each screen door), and the distance y from the platform staircase refers to the final distribution of waiting passengers at different waiting positions. Studying the functional relationship between the three is helpful in analyzing the formation process of waiting choice behavior and distribution of platform passengers from a macro perspective. In the first chapter, the relationship between the three parameters is studied in a standard station environment, combined with actual data.

4.1. Overall Distribution Pattern of Platforms

The relationship between the passenger flow at the platform entrance and the final distribution needs to determine a waiting location, and this section will discuss the different locations in sequence.

For waiting positions close to the staircase, as the passenger flow at the entrance increases, the number of waiting passengers increases. Due to capacity limitations, the number of waiting passengers will no longer increase after reaching the maximum value a. The flow of people will be diverted to waiting positions farther away from the staircase, as shown in Figure 2.

For waiting positions far away from the staircase, as the passenger flow at the entrance increases, the number of waiting passengers will increase. Due to the continuous flow of passengers from positions close to the staircase joining, the number of waiting passengers will sharply increase, as shown in Figure 3.



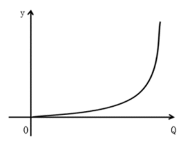
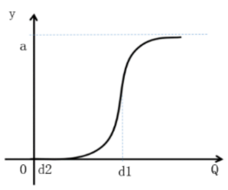


Fig 2. Waiting position close to the stairway **Fig 3.** Waiting position away from the stairway

However, each waiting position has its own capacity, and as the number of waiting passengers continues to increase and approaches the capacity, the trend of increasing the number of waiting passengers slows down, and after reaching the maximum value a, it will no longer increase. Unify the analysis of the two images in this section, and ultimately generate the image in Figure 4. From point d1 to point d2, it displays the trend of the distribution of people at various waiting positions from close to the staircase to far away from the staircase.

Although the number of people in each waiting position continues to increase as the entrance flow continues to increase, the probability of allocation is different for each waiting position: for waiting positions close to the staircase, as the total number of entrances increases, the proportion of people in this waiting position distribution to the total flow P gradually decreases from the initial b value ($b \leq 1$), and as it approaches the capacity, the probability reduction tends to be smooth, The final approach approaches 1/n (n waiting positions) as shown in Figure 5.



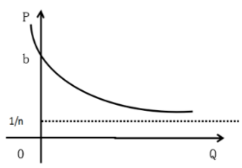


Fig 4. Normalization analysis **Fig 5.** Distribution probability of waiting positions close to the stairway

For the waiting positions far from the staircase, when Q=c, there is a distribution of people in the waiting positions far from the staircase. As the entrance passenger flow Q increases, the proportion of people in this waiting position distribution to the total flow P increases, and it increases rapidly in the initial stage, but slowly in the later stage, and finally approaches 1/n, as shown in Figure 6.

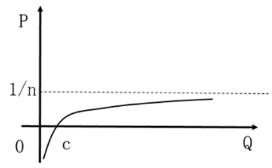


Fig 6. Distribution probability of waiting position away from the stairway

4.2. Regularity of Changes with Platform Flow

Observing the relationship between waiting positions and the number of waiting passengers at a certain driving interval requires studying under a determined flow environment. For ease of understanding, μ The distance between the waiting position and the staircase is a positive value (or at d>μ） The area represents the waiting position in front of the staircase, and the distance between the waiting position and the staircase is negative (or at d<μ） The area represents the waiting position behind the staircase side, as shown in Figure 7. Due to limitations in capacity and facility location, the number of waiting passengers is limited and there is no significant change. At the same time, there are almost no passengers waiting outside the distance.

In response to the above analysis, 20 sets of platform data from actual research were used to establish platform distribution maps under different flow conditions. Column analysis and curves were drawn using MATLAB software, as shown in Figure 8. The horizontal coordinates of the image from 1 to 10 represent the change in waiting position from the end of the platform to the middle of the platform.

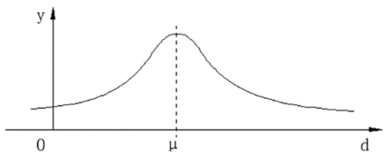


Fig 7. Distribution diagram

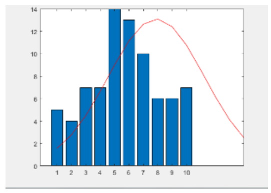


Fig 8. Fitting results of different data

According to the image, the fitting curve does not exhibit a complete normal distribution, but rather a skewed distribution. In the case of group spacing grouping, the calculation of mode should consider the distribution of adjacent groups in the group where the maximum frequency is located. The calculation formula is as follows:

$$M_0 = L + d \times \frac{\Delta_1}{\Delta_1 + \Delta_2}$$

In the formula, L is the lower limit value of the group with the maximum frequency, d is the group spacing of the group with the maximum frequency, Δ_1 is the difference between the frequency of the group with the maximum frequency and the frequency of the previous group, Δ_2 is the difference between the frequency of the group with the highest frequency and the frequency of the next group

The skewed distribution is because in a standard station environment, passengers have a visual blind spot behind the staircase after exiting, and they are more willing to choose the area in front of the staircase with a wide field of view.

In order to more accurately verify the skewness distribution of the data, it can be determined based on the skewness value: the closer the skewness SK approaches 0, the more the data follows a normal distribution, and the mode, median, and mean are equal; SK>0, positive skewed or left skewed, from small to large: mode, median, mean; SK<0, negative skewed or right skewed, from large to small: mode, median, mean, the results are shown in Table 2. The skewness of most data is greater than 0, indicating the right deviation of the data image, and also verifying the rule that passenger distribution is more concentrated towards the front of the staircase in a standard station environment. The kurtosis of each group of data in the table are mostly less than 0, indicating that the distribution image is close to a flat peak and the distribution is relatively scattered. It also verifies that in a standard station environment, passengers are not completely concentrated in a waiting position, but are selectively relatively dispersed.

Table 2. Data skew test

Total quantity Q	standard deviation	skewness	kurtosis
68	3.4	1.046	-0.165
62	3.7	0.154	-0.938
74	3.6	-0.049	-1.542
67	2.9	0.129	0.224
85	4.5	-0.175	-1.535
82	4.1	0.291	-1.377
82	3.6	-0.038	-1.001
85	3.7	0.3	-0.898
74	3.9	0.544	-0.412
68	4.2	-0.013	-1.766
63	3.8	0.469	-1.2
66	3.2	-0.103	-1.677
71	3.6	0.041	-1.596
67	2.5	-0.245	-1.473
64	2.5	-0.186	-2.049
81	3.2	-0.379	-1.853
79	3.4	-0.208	-1.346
72	3.1	-0.291	-1.978
82	3.1	-0.232	-1.991
86	3.1	-0.024	-1.796

Based solely on skewness and kurtosis is not sufficient to determine whether the data follows a normal distribution, and further testing is needed. Table 3 shows the results of the generated KS test (D test) and SW test (W test), and the significance we focus on here is Sig, which is the P-value. When P>0.05, it can be considered that the data is normally distributed. Due to the fact that the sample size is 10 and the results of the SW test are considered small, the significance here is greater than 0.05, indicating that the data is normally distributed.

Perform a QQ chart test on the goodness of fit of the data distribution. It can be seen that after normal fitting, the error between the probability line of the measured value and the theoretical value of the passengers at the platform is small, so it is believed that the passengers at the platform follow a normal distribution, as shown in Figure 9.

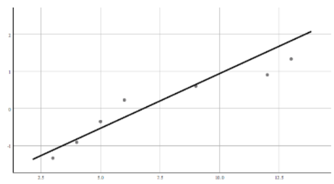


Fig 9. QQ chart inspection

4.3. Unified Analysis

Characterize the distance distribution population image under different traffic conditions in one graph. As shown in Figure 10, as the flow rate increases, the curve changes more smoothly.

As shown in Figure 11, the growth rate of each point from d1 to d5 is different (d1 is closer to the staircase, d5 is farther): as the relative distance between the waiting position and the staircase increases, the growth rate becomes faster (Q1＞Q2＞Q3＞Q4＞Q5 in the figure). At point d1, the initial volume is large, but it quickly approaches the saturation capacity a at this location. At point d5, the initial volume is small, but the growth rate continues to accelerate, and ultimately it also approaches the saturation capacity a at this location. This further validates the point 3.1 in this article.

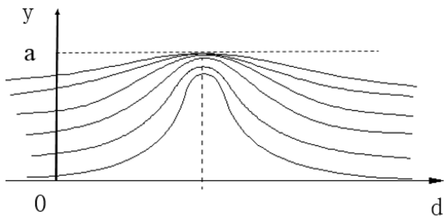
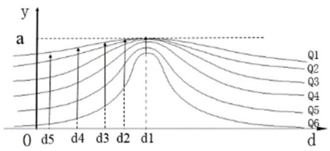


Fig 10. Flow superposition

From the distribution probability of the number of people in each waiting position to the total number of people, as shown in Figure 12, the image tends to be flat, and the probability of each position gradually approaches equal, as described in 3.1, approaching 1/n.



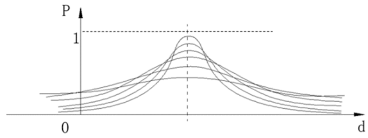


Fig 11. Growth rate in different locations

Fig 12. Probability changes of different positions

5. Conclusion

Based on the analysis of passenger behavior characteristics and platform construction characteristics, this article constructs a normal distribution model for rail transit platform passenger distribution, and conducts image analysis of various influencing factors. The following conclusions are drawn:

(1) The distribution of passengers at the platform follows a normal distribution pattern.

(2) As the platform traffic increases, the distribution variance decreases and the distribution changes from a normal distribution to a uniform distribution.

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