Comparison and Selection of Reconstruction Schemes for Transfer Channels of Zhichun Road Station in Beijing Subway Based on Pedestrian Simulation

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Abstract. As the most critical facility of the rail transit station, the transfer channel's capacity and efficiency greatly affect the operational efficiency and safety of the transfer station. Due to the uncoordinated network planning and the inaccurate prediction of passenger flow, the current capacity of the transfer station at the peak of the transfer station is seriously insufficient. It is necessary to redesign and rebuild the transfer channel to meet the needs of passengers in the peak period. Taking the Zhichun Road Station of Beijing Subway as an example, this paper uses the Vissim pedestrian simulation software to establish different transfer channel reconstruction schemes due to the problems caused by insufficient capacity of the transfer channel. Based on the actual transfer and facility capabilities, comprehensive considerations are made from the transfer time, transfer distance and reconstruction costs to arrive at the best retrofit solution.

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1. Introduction

With the continuous expansion of the urban rail transit network, the status of the interchange hub has become more and more prominent, which has become the main factor affecting the efficiency and service level of rail transit [1]. In the construction process of the interchange hub, the impact of transfer mode and transfer efficiency on the operation of the rail transit system becomes more and more obvious [2]. The transfer form of rail transit can be divided into basic forms such as channel transfer, same station transfer, and node transfer. When the two stations are not adjacent, the channel transfer mode is the best choice [3]. For a station with a transfer mode of channel transfer, the transfer channel is generally a one-way passenger flow, and there is no interference to the passenger flow, but the passenger flow at the transfer station is large. When the passenger flow is constant, the wider the transfer channel is, and the longer the length is, the smaller the passenger flow density is in the channel, and the smaller is the mutual interference between the passengers before and after; on the contrary, the mutual influence of the passengers will increase, the travel speed is limited, and local high-density passenger flow occurs. Congestion occurs. In addition, the shape of the channel will also have an impact on the passenger flow. In the sudden change of shape, local high-density passenger flow will occur, resulting in congestion.

Scholars have done a lot of theoretical research on channel transfer. Li Can (2008) [4] established the speed-density relationship model of the inner passage of the hub by means of field observation and data acquisition, and calibrated the basic parameter values of passenger traffic characteristics in different pedestrian facilities, which is the internal passage of the domestic orbital transfer station. The
design provides a certain theoretical basis. He Liying, Wang Zhongyue, and Jiang Lihua [5] used Legion to establish a pedestrian simulation model of the transfer station, and counted the transfer time and transfer channel usage between the two lines, and observed whether a bottleneck would occur. Wang Yang (2010) [6] used the simulation software Vissim to construct an improved model of the existing subway station with channel transfer mode, and explained the reduction of the transfer time after the improvement by the average travel time of the pedestrian. Zhu Competition (2012) [7] based on passenger characteristics of passenger transfer, passenger flow characteristics and capacity analysis of each transfer facility, the passenger flow density is used as the main index to divide the comfort level of the transfer channel, and the channel length is used as the index to divide the channel convenience. Level, and according to the wooden barrel principle, the service level comprehensive evaluation standard of the transfer channel is obtained. He Wen (2013) [8] analyzed the channel utilization, pedestrian density and speed of different types of channels through simulation modeling, and obtained the maximum passenger flow adaptation range of different shape channels under the specified channel size. Based on the existing theoretical research, this paper takes the reconstruction project of Zhichun Road Station of Beijing Subway as an example. Starting from the two aspects of channel size and plane shape setting, using simulation software to construct different optimization simulation schemes and carry out simulation evaluation. The optimization proposal for the construction of the transfer channel has been proposed.

2. Transfer Channel Design Overview

2.1 Transfer channel design method

The transfer passage (hereinafter referred to as the passage) is at the intersection of the two subway lines, the structure of the station is completely disengaged, and the two stations are connected by channels and stairs, which is an indirect transfer form. The regulation of the channel in China mainly considers the construction length and width of the channel, and considers the normal operation state and emergency evacuation state of the subway station.

China's "Urban Design Code (GB_50157-2013)" for the overall design of the channel is as follows: the length of the underground station channel should not exceed 100 meters, if more than 100 meters, you can set up a moving walkway; the minimum width of the channel is 2.4 meters, the minimum height is 2.4 meters , the passage ability of the channel is shown in Table 1:

Please follow these instructions as carefully as possible so all articles within a conference have the same style to the title page. This paragraph follows a section title so it should not be indented [2-3].

| Part name                      | Number of people passing per hour | Number of people per minute |
|--------------------------------|----------------------------------|-----------------------------|
| Unit wide channel (one way)    | 5000                             | 83                          |
| Unit wide channel (two-way mixed line) | 4000                         | 67                          |
| Unit width automatic walkway   | 9600                             | 160                         |

When designing a station, based on the general provisions of the specification, it is necessary to consider the peak hour passenger flow of the subway station during planning and the width design of the corridor for the escalator. At the same time, according to the operation status of the subway station, it can be divided into the channel width required for normal operation and the channel width required for the emergency evacuation state.

\[ B = \frac{Q}{N} + M \]  

formula (1)
In formula (1):

- **B**: channel width (m);
- **Q**: hourly passenger flow, the number of people passing in the hourly period (person);
- **N**: The maximum passing capacity of the channel, there is a two-way passenger flow when entering the station, taking 67 people/m/min;
- **M**: width (m) of the appendage in the channel, taking 0.3 m;

For the calculation of Q (hour passenger flow), it should be determined according to the layout of the building escalator at the entrance and exit. Under normal circumstances, the 1m wide full-load escalator has a passing capacity of 135 people/min, and a staircase with a width of 2m can simultaneously walk three people at the same time, and its downward passing ability is $3 \times 35 = 105$ people/min. For stairs of other widths, 0.55m is taken as an equivalent width, and the passage capacity per 0.55m is 35 people/min. The value of Q is the sum of the passenger flow of the escalator and the stairs.

(1) Channel width required for normal operation

The size of the station passage is generally determined based on the passenger flow calculation based on the requirements for disaster prevention. Its calculation method is usually as follows:

2.1 Emergency evacuation state design

In the case of emergency evacuation, escalators and stairs are available for upward use. The escalator is used as a stairway and the escalator is to be reduced by one as a damage consideration. The formula for calculating the width is as follows:

$$B' = \frac{Q'}{N'} + M'$$

In formula (2):

- **B'**: the required channel width for emergency evacuation (m);
- **Q'**: hourly passenger flow, number of people passing through the hour per hour under emergency evacuation (person);
- **N'**: the ability to pass every hour, only the upstream passenger flow when entering the emergency exit, taking 83 people/min;
- **M'**: width (m) of the appendage in the channel, taking 0.3m;

For the calculation of Q' (hour passenger flow), the 1m wide escalator is used as a 1m wide staircase in the case of emergency evacuation, and its upward passing capacity is 62 people/min; the other stairs are capable of passing upwards per 0.55m for 31 people/min. The value of Q' is the sum of the passenger flow of the escalator and the stairs.

Consider the general provisions of the specification regarding the design of the channel, taking the larger values calculated according to normal conditions and by emergency. Among them, if the passage directly leads to the stairs or the escalator, its capacity must be at least equal to the capacity of the stairs or escalators.

2.2 Transfer Channel Frequently Asked Questions

(1) The deviation between actual passenger flow and predicted passenger flow is large

Due to the regional development and the uncertainty of regional policies, the passenger traffic at the initial stage of the subway station planning is often deviated from the passenger flow after the station is put into operation, especially in the large residential areas and office centers, the actual passenger flow and the predicted passenger flow. The difference is large. It often leads to the existing facilities built according to the forecast that can not meet the actual passengers' entry and exit requirements, which brings great security risks to the operation.

(2) The ability to transfer channels is insufficient, and there are potential safety hazards.

Xuanwumen of Beijing Metro is the transfer node of Line 2 and Line 4. According to the survey, Xuanwumen Station reaches the peak of transfer from 7:30-8:30, and the maximum transfer is about 14,000 passengers/hour.: 30-18:30 to reach the peak of the transfer, the maximum transfer amount is
about 9,800 person / hour. The effective width of the transfer passage stairs is only 2.2 meters. It is easy to form a bottleneck during the transfer. There are more passengers on the platform, and the passengers are close to the yellow safety line, which has serious safety hazards.

(3) The passing ability of different parts in the same transfer channel is uncoordinated, and there is a traffic bottleneck, which affects the overall evacuation efficiency.

The Beijing Subway Chongwenmen Station is a typical channel transfer. The passenger flow between Line 2 and Line 5 is transferred through two one-way channels. During the transfer of Line 5 to Line 2, the capacity of the passengers passing through different parts of the station was seriously mismatched, especially the stairs entering the platform of Line 2, and the 3.2m wide stairs were converted according to the subway design specifications. The capacity was 11,840 people/h. The connection channel conversion capacity is 15,750 people/h, which leads to smooth running in the channel and serious congestion at the stairway.

3. Transfer channel optimization method

Vissim is a microscopic traffic simulation software developed by German PTV Company. Because of its accurate simulation results and strong visual effects, it is often used in engineering practice, such as traffic flow simulation, building evacuation and subway station passenger flow stream simulation. In the optimization and reconstruction of the transfer channel, the micro-traffic simulation software is used to compare the channel remodeling schemes from the passenger flow organization and channel facility optimization.

3.1 Passenger flow organization optimization

In the operation phase of the subway, because the transfer channel cannot be rebuilt, the main means of passenger flow organization optimization is to reduce the collision of passenger flow and reduce the traffic of key nodes. Add a guardrail in the middle of the two-way transfer channel to reduce passenger flow conflicts. Figure 1 uses Vissim to create two transfer channel models, each with a size of 4m × 20m, inputting a passenger flow of 4000 people/h at both ends, and adding a guardrail in the middle of the lower channel to make passengers flow in both directions. Separation. The simulation results show that increasing the guardrail can reduce pedestrian conflict and shorten travel time and distance.

![Figure 1. Two-way transfer channel plus guardrail front and rear diagram](image)

In order to avoid the safety hazard caused by a large number of passengers gathering in the platform and the traffic facilities in a short time, a narrow passage surrounded by railings may be provided at the entrance to reduce the flow of the key nodes. As shown in Fig. 2, two transfer channels are established by VISSIM, one is 40m×3.2m, one is 40m×2.4m, and the stairs connected to it are 3.2 meters wide, and the input passenger flow is 6000 people/h. The simulation results show that the setting of the narrow channel can effectively control the passenger flow density on the stairs connected to it, and ensure the safety of passengers.
Figure 2. Schematic diagram of different width transfer channel models

3.2 channel facility optimization
When the subway passenger transfer conflict is more serious, and the passenger flow organization optimization effect is not obvious, consider optimizing the channel facilities, mainly by expanding the channel capacity and optimizing the channel layout. Newly built and widened channels can expand the channel capacity. For example, the Beijing subway Xuanwumen station has a serious passenger flow conflict. The Beijing Subway has created two new transfer channels to allow passengers to divert, greatly reducing the existing conditions and reducing confliction time.

If large-scale sizeening of existing stations is limited in terms of project feasibility, it is possible to improve the throughput by optimizing the channel layout, such as changing the channel facility to a gradual change. The sudden change of the channel is a bottleneck of passenger flow impact. The passengers visually have obstacles in the passage of the mutation to prevent the feeling of going forward, so they will subconsciously slow down and form a queue. Changing the mutation to a funnel-shaped gradient, or rounding the channel at a right angle, can improve the smoothness of the pedestrian through the bottleneck. For the optimization of the channel mutation, a channel length of 20m, a width of 4m, a width of 2.5m, and a channel passenger flow of 6,000 people/h are established, as shown in Fig. 3. The results show that after changing the right-angle mutation into a funnel shape, the average travel distance, time, and delay time are reduced, and the average speed is increased, indicating that the mutation is made into a rounded gradient form, which can effectively improve its ability to pass.

Figure 3. Comparison of the model before and after channel optimization

4. Example simulation of the transfer channel of Zhichun Road Station
In this chapter, based on the above-mentioned channel transfer optimization method, based on the current situation of the transfer of Zhichun Road Station in Beijing Subway, a practical design scheme is proposed considering the engineering cost, and the design scheme is simulated by Vissim simulation from the perspective of passenger flow density and pedestrian transfer time. Compare and judge.

4.1 Project Overview
Zhichun Road Station is a transfer station for Metro Line 10 and Line 13, which has a huge passenger flow. Connected via an underground transfer channel. Figure 4 shows the model map of Zhichun Road
Station. The transfer lane is now 7 meters wide. There are two 1 meter wide escalators and a 2.2 meter wide staircase at the South Station of Line 13.

![Figure 4. The original transfer channel of Zhichun Road Station (red and blue filled)](image)

Table 2 shows the passenger flow data table of Zhichun Road Station on Line 13. It can be seen from the table that the passenger flow of Zhichun Road Station on Line 13 is mainly for passenger flow. Among them, during the morning rush hour, the transfer amount of Line 13 to Line 10 is: 10300 people/h, and the passenger flow in the upstream direction is large; the transfer amount of Line 10 and Line 13 is: 6810 person/hour, and the transfer in the evening rush hour, the traffic of Line 13 and Line 10 is 8400 passengers/hour and the passenger flow in the upstream direction is large; the traffic of Line 10 and Line 13 is: 9500 passengers/Hours, and the passenger traffic in the down direction is large. The mismatch between the transfer channel and the transfer amount can not meet the huge passenger flow demand, forming a bottleneck, and there are many passengers stranded on the platform, which has serious safety hazards.

| Passenger flow type   | All day (10,000 people) |
|-----------------------|-------------------------|
| Transfer amount       | 8.43                    |
| Inbound volume        | 1.89                    |
| Outbound volume       | 1.95                    |

4.2 Reconstruction plan research

In view of the problems existing in the transfer channel of Zhichun Road Station, this section proposes the following two feasible reconstruction schemes, establishes the models of these reconstruction schemes, and performs simulation simulations to compare the options from the perspective of passenger flow density and pedestrian transfer time. Among them, the two considerations of civil construction feasibility and cost are not repeated here.

(1) Reconstruction plan 1

As shown in Figure 5, the transfer channel model of the remodeling scheme 1 was established with Vissim, with a net width of 4 meters and a total length of 155 meters. On the south side, a set of 1m clear width escalators is set up, and on the north side, a set of 2m clear width stairs is set up, occupying 50 square meters of the station hall, and inputting 9000 person/h of passenger flow for simulation.
4.2 Reconstruction plan 2

As shown in Figure 6, Vissim is used to establish the transfer channel model of the remodeling scheme 2, and a new north transfer passage is created, with a net width of 6.6 meters and a total length of 136 meters. A set of stairs is set, and a passenger flow of 9000 people/h is input.

4.3 Scheme comparison

Figure 7 shows the density LOS diagram of the original plan, the remodeling plan 1 and the remodeling plan. It can be seen that the original channel is congested in many places such as the escalator opening and the passage. Option 1 adds a north transfer channel, which increases the passing capacity of the transfer channel, effectively alleviating the congestion in the descending stairs and passages of the South Station Hall on Line 13, but the passage of the descending stairs in the station hall on Line 10 The ability has not improved, forming a bottleneck. A large number of passengers flowed into the station of Line 10 at the same time, causing severe congestion at the downstairs. Scheme 2, although the transfer distance is slightly longer, effectively achieves the dispersion of passenger flow and does not form obvious congestion.
The passengers traveled in three cases and the simulation time was 600s, as shown in Table 3. As can be seen from the data in the table, the travel time of the scheme 2 is also reduced by 31 seconds compared with the scheme 1. Comprehensive comparison of passenger flow density and pedestrian travel time, Option 2 is the best optimization plan.

| parameter       | original plan | Reconstruction plan 1 | Reconstruction plan 2 |
|-----------------|---------------|------------------------|-----------------------|
| Walking time (s)| 168           | 227                    | 196                   |

5. Conclusion
The transfer channel is a key part of the subway transfer station. This paper introduces the design and optimization of the transfer station. Taking the Zhichun Road Station of Beijing Metro as an example, a solution is proposed for the status quo, and the proposed scheme is compared and evaluated from the perspective of passenger flow simulation. The reconstruction scheme 2 proposed in this paper, although increasing the passenger's transfer distance, can effectively reduce the evacuation time and reduce the congestion.

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