Chapter 7
Comparative Study on the Transfer Efficiency of Triple-Line Transfer Station for Urban Rail Transit

Chuanfeng Wan, Shaoman Liu, and Xiaobo Yan

Abstract The paper defines different design conditions of triple-line transfer station type under simplified assumptions and presents the concept of transfer efficiency from the point view of urban rail transit network. Then, it builds simulation models of seven typical transfer patterns with Vissim, extracts the time of each transfer direction to compare the total transfer time by loading different passenger flows on different triple-line stations. Finally, taking into account other factors which have impact on station type selection, the paper provides guidance on lectotype design of triple-line transfer station.

Keywords Triple-line transfer station • Vissim simulation • Transfer efficiency • Lectotype design

7.1 Introduction

With the sustainable economic development and the accelerated pace of urbanization in China, the number of cities with urban rail transit constructed or planned is increasing rapidly. Rail transit in several big cities has entered the period of relatively mature network construction and operation. The urban rail transit network presents complex characteristics. As an important part of it, the transfer station plays an essential supporting role for the network transfer efficiency [1].

With the further construction of urban rail transit in our country, the number of multi-line transfer stations especially triple-line transfer station will increase [2].

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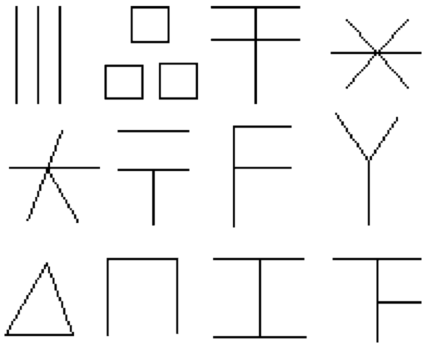

Fig. 7.1 Triple-line transfer patterns

These stations attract a large number of passengers and the organization among transfer passengers is complex. Whether the lectotype design of triple-line transfer station is reasonable, or can meet the transfer requirements, will directly determine the efficiency of the entire network. However, the transfer station research home and abroad focuses more on two-line transfer station. There is no standard design guidance triple-line transfer station. Through modeling seven typical three-line transfer stations patterns and calculating transfer efficiency under the assumed same transfer passenger flows. The paper can provide the basis for lectotype design of triple-line transfer station.

7.1.1 Pattern Analysis of Triple-Line Transfer Station

For a single transfer station, the number of patterns is related to the number of lines which transfer station connects to. With the different mutual relationship of the two platforms, two-line transfer station has four different types: "十", "T", "L" and "—" [3]. Based on the four basic patterns, there will be 12 transfer types for triple-line transfer station. The specific combinations are shown in Fig. 7.1.

The transfer types of triple-line transfer station have a variety of combinations according to the difference of the line direction, the line position in space (ground, underground, elevated), and the layouts of the platforms. According to the number of line intersecting nodes, the triple-line transfer station has the following representative transfer type: "川", "品", "Y", "大", "H", "F", "△".

7.2 Method on Transfer Efficiency Analysis

7.2.1 Assumptions on Facilities

For the different transfer types, the layout and design of the facilities follows Code for Design of Metro. The maximum capacity of corresponding facilities is calculated with maximum passenger flows which is 14,400 people per hour.

Transfer passages are assigned with the width of 5 m without middle railings. Transfer stairs is 4 m wide. Stairs at the end of platform is 6 m wide. The escalator width is 1 m. All the platforms are compatible with 6 B-type cars with the width of 13 m island platform.

7.2.2 Assumptions on Simulation Model

7.2.2.1 Basic Assumptions for Simulation Model

The model used in this study simulates the passengers' dynamic changes for triple-line transfer station based on the following basic assumptions [4]:

1. The platform, the station hall, stairs, escalators are simulated with different segments;
2. The passengers decide the path and, move with pre-assigned speed;
3. The model uses the time step of 10 simulation seconds/seconds;
4. The arrival of each train is independent and randomly;
5. The simulation will be finished when all passengers reach their expected transfer platform.

7.2.2.2 Assumption on passenger speed

Most passengers in subway hub have their own specific purposes especially in morning/afternoon peak hours commuters. Because of large passenger flow, there will be queuing or congestion for some facilities. So, the walking speed of passengers will greatly reduce. In this paper, the simulation speed for passenger flow is 1.1 m/s which is higher than peak hour as normal situations.

Passenger' speed on staircase and escalator is different from station hall and platform. The stair speed is 0.7 m/s and escalators speed is 0.65 m/s. When passengers reach the stairs or escalators, the walking speed changed to the pre-assigned speed.

7.2.2.3 Assumption on Transfer Facilities

Transfer facilities include stair, escalator, station hall and platform. Passengers' walking in the station hall and platform is similar to that in the segment. So the station hall and platform can be simulated as segment. The capacity of the stair and escalator is based on their width and numbers. So, it is possible to match simulation capacity with actual capacity by simulating stair and escalator as segment and taking speed deceleration measures. The platform layer, station hall, stair and escalator are all simulated with actual sizes.

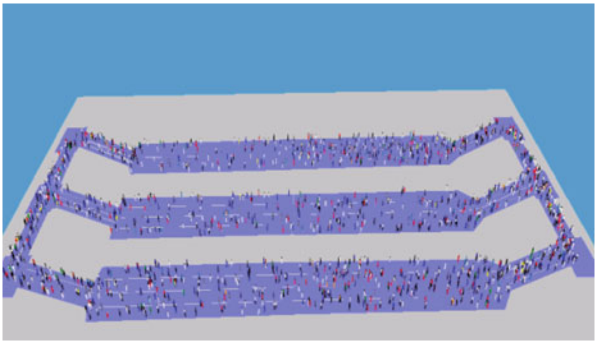

Fig. 7.2 Simulation model for pattern of "川"

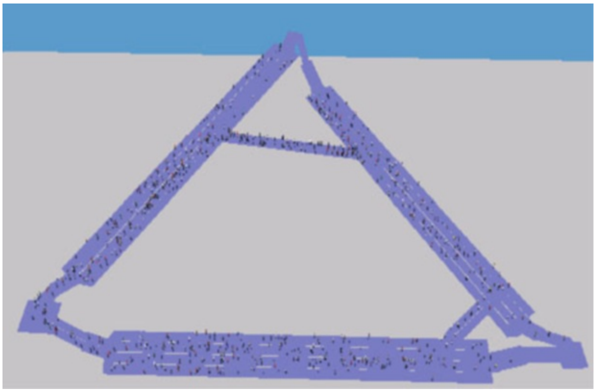

Fig. 7.3 Simulation model for pattern of "Δ"

7.2.2.4 Rule of Passenger Route Choice

The model assigns the same proportion of passenger route choice according to different transfer directions in the seven triple-line transfer station, and passenger walking route in the model is the same as the actual transfer routes.

7.2.3 Simulation and Calculation

We Simplify passenger flow direction of triple-line transfer station into a triangle, each edge is a primary transfer direction, so each edge has eight transfer directions. The paper mainly simulates and calculates the transfer time of the three edges, and compares the differences of transfer patterns. The simulation process assumes that the transfer passenger is consistent which means the same passenger flows and consistent changes for different transfer direction.

Simulation models of seven typical three-line transfer stations are built as follows; the operational process is showed in the following Figs. 7.2, 7.3, 7.4, 7.5, 7.6, 7.7, and 7.8.

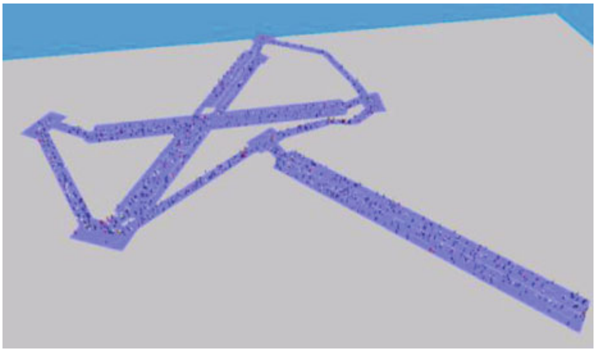

Fig. 7.4 Simulation model for pattern of “大”

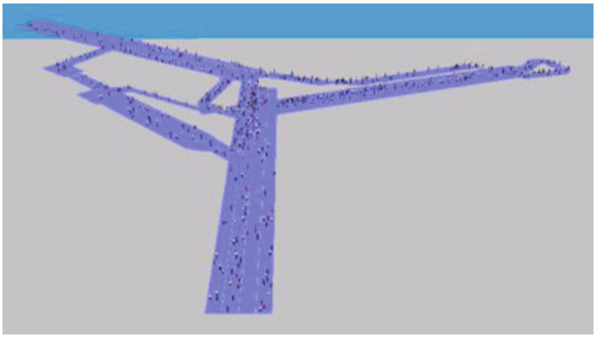

Fig. 7.5 Simulation model for pattern of “Y”

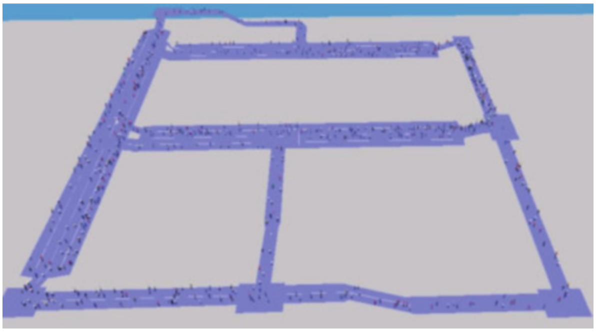

Fig. 7.6 Simulation model for pattern of “F”

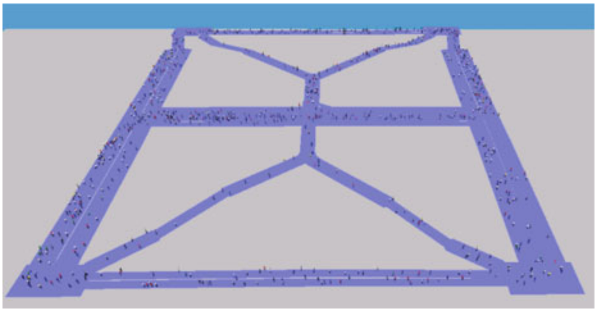

Fig. 7.7 Simulation model for pattern of “H”

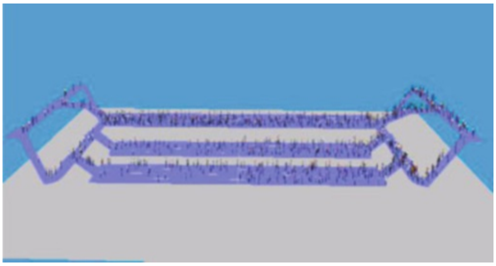

Fig. 7.8 Simulation model for pattern of “品”

Table 7.1 Transfer time

Type/passenger	500	1,000	1,500	2,000	2,500	3,000	3,500	4,000	4,500	5,000
川	350	701	1,057	1,418	1,788	2,163	2,546	2,941	3,336	3,740
Δ	460	921	1,387	1,858	2,336	2,831	3,329	3,841	4,251	4,877
大	622	1,245	1,872	2,506	3,149	3,802	4,463	5,128	5,807	6,502
Y	630	1,261	1,897	2,538	3,188	3,855	4,538	5,234	5,940	6,650
F	586	1,154	1,740	2,336	2,937	3,562	4,198	4,847	5,506	6,177
H	523	1,047	1,576	2,117	2,651	3,214	3,788	4,377	4,974	5,581
品	400	801	1,213	1,637	2,073	2,520	2,974	3,442	3,913	4,398

Passenger flows is loaded from 500 to 5,000 people per hour for 24 transfer directions in each model, and total transfer time is extracted shown in Table 7.1.

7.3 Comparison Analysis

As shown in the above chart, the transfer time of “川” is minimum, and the type of “Y” is maximum. According to the definition of transfer efficiency, when the transfer passenger is consistent, the efficiency is higher with the least transfer time, in which the sequencing of transfer efficiency is: “川” > “品” > “Δ” > “H” > “F” > “大” > “Y” (Fig. 7.9).

With the same passenger flows and consistent change of different transfer direction, the transfer time is mainly affected by the transfer distance. Pattern of “川” transfer station realizes six transfer directions while pattern of “品” realizes four directions. So, the efficiencies of these two types of transfer stations are higher than other patterns. The transfer distance for the pattern of “大” and “Y” is long, so the total transfer time is also long compared to others, and the transfer time of these two patterns is very close.

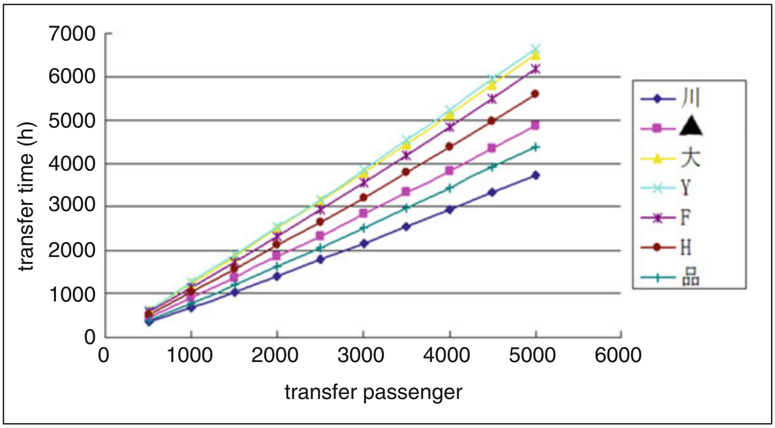

Fig. 7.9 Comparison chart of results

7.4 Reasonable Pattern for Triple-Line Transfer Station

The triple-line transfer station is a huge project. It's hard to be finished at the same time. The more passenger flow direction in transfer stations, the more difficult to organize the passenger flow. The following factors should be considered when selecting the transfer station pattern:

7.4.1 Construction

The construction cost directly affects the investment on subway because it accounts for a large part of the total cost. In general, the construction cost for underground station is higher than elevated station while the cost of ground station is minimum [5]. The construction cost of cross-platform interchange is higher than ordinary one, and the cost is also higher if not implemented at the same time. So, the pattern of-"川" transfer station is hard to be done if considering the feasibility of construction.

7.4.2 Project Reserved

Combining the construction planning of the subway lines, it is less likely to construct three lines in the same time. Different type of transfer station has different reserved project, and the difficulty to reserve has a great difference. Considering the conditions of reservation node and transfer channel interface by stages, the more line intersections are, the more convenient the reserved project is. Therefore, the reserved works of type-“ Δ” and “ H” transfer station is convenient.

It’s hard to construct three lines at the same time. Different transfer station pattern has different reserved project. Considering the conditions of reservation node and transfer passage interface for different phases, the more in pattern of “Δ” and “H” transfer station is more convenient for reserved works compared to others.

7.4.3 Transfer Passenger

Transfer passenger volume is a very important part to select the transfer station pattern. Based on the changes of passenger flows, appropriate pattern of transfer station can be chosen to improve the transfer efficiency with the reduction of construction investment [6]. From the simulation, we can see that:

When passenger flow of each transfer direction are equal or have little difference between them, The cross-platform interchange for some direction should be selected as far as possible based on the line routes in order to achieve higher transfer efficiency. But, when they are not equal, if the transfer passenger flow is less on shorter transfer distance, the advantages of transfer fail to reflect obviously.

7.5 Conclusions

Based on the comparative analysis on transfer efficiency of triple-line station, the number of transfer nodes and the presence of the cross-platform interchange, the efficiency order is: The station with cross-platform has the highest efficiency; Usually, the transfer efficiency of triple-line station is based on the nodes. The efficiency with the intersection of three nodes is higher than that of two nodes which is higher than that of one node.

When planning and designing urban rail transit network, it’s important to design line directions and transfer pattern appropriately. Triple-line transfer station should first ensure cross-platform interchange, and then try to realize the intersection of each two lines. Considering the aspects of construction costs, project reserved, the convenience for transfer passengers and the accessibility of the passenger flow organization and management, The order of transfer efficiency for triple-line station pattern is pattern of “Δ”, “品”, and “H”.

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