The application of urban rail transit station connection guidelines in mountain city pedestrian transfer

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Abstract. Rail transit takes the advantage of large volume and fast speed as the first choice for many people to travel, and the way of pedestrian transfer is the preferred way for residents of mountainous cities. Compared with plain cities, the sharing rate of pedestrian transfer in mountainous cities is higher. However, due to the large vertical elevation difference in most mountainous cities and the urban characteristics of group development, there are problems of poor connectivity of pedestrian network, inadequate interchange crossing facilities and large bypass distance in the pedestrian transfer in mountainous cities, which causes potential safety hazards and inadequate convenience for pedestrians to travel. By redefining the actual transfer distance and the planning and design scope, this paper analyses the pedestrian transfer characteristics of mountainous cities from a psychological point of view. Taking Chongqing as a typical mountainous city as an example, based on the newly issued Guidelines for Connecting Rail Transit in Chongqing, the application of the Guidelines in actual projects is analysed to prove the generalization of the Guidelines.

1. Introduction
With the development of economy and the improvement of living standard, urban rail transit has become an inevitable product of the development of the times. Therefore, in order to better meet the "last kilometer" travel needs of citizens, it is necessary to form an integrated transportation connection system with rail transit stations as the core. However, for mountainous cities, the terrain characteristics of large height difference make it difficult to connect the traffic around the urban rail station, which is fundamentally due to the imperfection of the walking system. Based on the characteristics of mountain cities, the traffic connection guidelines provide technical support for the planning and design of traffic connection facilities.

2. Characteristics of pedestrian transfer in Mountainous Cities

2.1. Psychological needs of walking transfer
The characteristics of pedestrian transfer in mountain cities refer to the behaviour and psychological characteristics in the process of choosing pedestrian mode for rail connection. According to the theory of pedestrian traffic psychology, pedestrian hope to get to their destination freely, conveniently and quickly. This psychological characteristic makes the pedestrian have the psychological phenomenon of "greedy for personal convenience" and "hope to travel easily", that is, to pursue the travel mode of time-saving and labour-saving, mainly manifested as "cut corner" and "less climbing".
2.1.1. "Cut Corner" This is also a manifestation of shortcut psychology. In the rail transit connection, the destination is clearly the rail station. Even in the main road with fast speed, the pedestrian transfer will choose to walk directly when they think it is safe. In order to show off for a while, this method will put the pedestrian transfer in the dangerous traffic flow, and at the same time, it will cause safety hazards for the smooth passage of vehicles.

2.1.2. "Less Climbing" There is a large height difference in mountain cities, which makes pedestrian often need to climb up and down in the process of rail transit transfer, because the uphill will cause greater psychological pressure on most pedestrian, which will greatly increase physical consumption physically, and also reduce the walking range and speed of walkers. The psychology of labor-saving will dominate the walkers to choose shorter distance, less change in walking speed and low fatigue to go to the railway station.

2.2. Definition of transfer distance
For mountainous cities, in the study of urban rail transit connection, it is not significant to use the horizontal distance between two points as the transfer distance. It is necessary to introduce the concept of actual walking distance to help define the transfer distance. In the study, the actual walking distance is defined as the sum of the total length of the road around which two points need to be connected by walking in space.

In practical projects, the psychological state of "short cut" and "less climbing" is usually measured by walking transfer distance and transfer time. Pedestrians want to spend less time and walk less distance to reach their destination. When the terrain is complex, the walking distance in the vertical direction should also be considered. Pedestrian route directness (abbreviated as "PRD", the same below) can help us understand the actual reachable distance of the pedestrian connection of urban rail station, that is, the ratio of the actual distance between the starting and ending points to the horizontal linear distance between the origin and destination. It can be seen that, in the case of a certain horizontal linear distance, the PRD value is in a positive proportion to the detour distance, and the larger the PRD value is, The more detours; and vice versa.

Figure 1. Schematic Diagram of "PRD" Value Calculating Method for Pedestrian Connection of Urban Rail Station

2.3. The planning and design scope of rail transit station traffic connection facilities
The planning and design scope of urban rail transit station traffic connection facilities is based on the radiation scope of pedestrian connection. It is determined by the product of pedestrian's walking speed and acceptable average time. In order to ensure the 10-minute walking accessibility around the rail transit station, the walking distance within 10 minutes should be 720m-900m according to the urban pedestrian's walking speed of 1.2-1.5m/s. When the PRD value reaches 1.8, it means that the actual
walking distance has reached 900m and the walking time has reached 15 minutes. There is a long detour to overcome the height difference. Considering the influence of terrain characteristics of mountain cities on walking speed and walking distance, the research scope is selected within 500m radius with rail station as the center. Therefore, it is proposed in Chongqing rail transit station traffic connection guidelines that the planning and design scope of rail transit station traffic connection facilities should be 500m away from the center of rail transit station in principle and related to rail transit functions. The purpose is to reduce the PRD value of points within 500m to less than 1.8 by means of connecting facility transformation, so as to improve the transfer efficiency and the utilization rate of rail station. Some entrances are located 500m away from the center of rail transit station due to the terrain restriction. The planning and design of transfer facilities should also be considered in combination with the relationship between the buildings around entrance and the surrounding land.

3. Problems of pedestrian transfer in Mountainous Cities

Different from plain city, the connectivity of road network is restricted by the complex vertical terrain characteristics and the cost of project. The location of the station is affected by shortage of land and the characteristics of group development. It is often difficult to give consideration to the location and the best passenger flow point, which indirectly increases the distance between pedestrians and the railway station, making the PRD value greater than 2, causing the inconvenience of transfer. Due to the large height difference in mountain cities, the main transfer problem in the process of overcoming the height difference is that the detour distance is too long. It is mainly reflected in two aspects.

3.1. Poor connectivity of pedestrian network

The insufficient combination of the pedestrian connection system and the terrain of urban rail station results in a large detour distance. Due to the lack of pedestrian connection facilities, two points with small vertical distance need to be bypassed for many times to connect, which increases travel time and reduces the convenience of passengers. For example, the horizontal distance between the Tongyuanju of Chongqing Urban Rail Line 3 station and Shuangfengshan road is only 410m, but due to the terrain elevation difference of nearly 50m, the traffic barrier is formed, which requires a detour of about 1.2km, and the transfer PRD value is as high as 2.86, as shown in Figure 2, affecting the pedestrian network connectivity.

![Figure 2. Detour problem in TongYuanJu Station](image)

3.2. Insufficient connection with crossing facilities

Insufficient connection with crossing facilities leads to large detour distance and unsafe travel of passengers. For example, in YuanJiaGang station of Chongqing Urban Rail Line 2, entrance A fails to connect directly with the First Affiliated Hospital of Chongqing Medical University. After passengers leave the station, they need to walk down to the sidewalk through the corridor and ladder, and then cross the Olympic road through the underground passage, as shown in Figure 3.
4. The application of urban rail transit guidelines
Take Chongqing as an example, in the process of compilation, the guide fully considers the psychological needs of the pedestrian interchange, aims to reduce the PRD value, and ensures the connectivity of the pedestrian network. From the perspective of engineering design, it puts forward qualitative and quantitative requirements for the setting of escalators and interchange crossing facilities.

4.1. Ensure the connectivity of pedestrian network
According to the guidelines, if it is necessary to detour due to terrain reasons (for example, broken road due to mountain block), so as to lead to a long distance of pedestrian connection, an elevator or step shall be set to open the broken road to ensure the connectivity of the pedestrian network. Taking HongTuDi station of Chongqing rail line 6 as an example, the straight-line path of pedestrian transfer is blocked by mountains to form a dead end road. As shown in Figure 4, the vertical height difference of 50m results in a two-point detour distance of only 220m, which is about 1.1km, and a PRD value of about 5.0. At the same time, it affects the willingness of passengers in the southern region to use the subway. According to the provisions of the guidelines, the external double steel stairs are added on the west side of Wuxing North Road to shorten the time for nearby residents to arrive at the station and reduce the PRD value to 1.1. Meanwhile, the service range of 500m walking connection near HongTuDi station is expanded by 30%, and the walking time within 500m is controlled within 10 minutes.

4.2. Escalator Setting
From the perspective of engineering design, when the continuous height difference reaches 15m, 93 steps shall be set up according to the specifications, which is equivalent to the height of continuous climbing five floors. For mountain cities, such terrain is normal, but from the perspective of the transfer experience of walkers, such design is dehumanizing planning and design concept. The escalator, to some extent, solves the problem of large height difference and meets the psychological needs of pedestrians who want to "climb less". From another point of view, if the height difference was originally presented in the form of a ramp, if a ramp was set up to estimate the maximum gradient of 1:12, when the
continuous height difference reached 15m, pedestrians need to walk on a ramp of at least 180m. The average walking speed of urban pedestrians is about 1.2m/s. As the uphill will consume more physical strength, the walking speed will be reduced. If the walking speed is calculated as 1.0m/s, the pedestrians will be uphill or downhill for 3 minutes, which is a far detour in mountainous city.

Taking TongYuanJu Station of Chongqing Rail Transit Line 3 as an example, the No.1 exit of the rail station is connected with Haitong road by 320 winding mountain terraces, and the number of steps between each two adjacent rest platforms is far more than 18 specified in the specification. According to the provisions of the guide that escalators should be set when the continuous height difference is greater than 15m, escalators should be added to the connecting road between Haitong road and TongYuanJu station to provide safe, convenient and comfortable travel environment for pedestrians.

![Figure 5. Sketch map of escalator on pedestrian road (TongYuanJu Station in ChongQing)](image)

4.3. Interchange Crossing Facilities
When a long-distance detour is required for pedestrian connection, according to the pedestrian's "cut corner" mentality, pedestrians will choose a more direct path. In the case of ensuring no collision with the traffic, they will ignore the traffic rules, cross the road, and fast walk forcibly. This kind of behavior will not only be irresponsible for their own safety, but also greatly interfere with the normal traffic of motor vehicles. In view of this situation, the guide stipulates that the interchange crossing facilities should be seamless transfer with the rail transit station, and the distance between the ladder and the subway entrance and exit should not be more than 30m when the conditions are limited. At the same time, it is required to set up independent pedestrian crossing channels when the space and pipeline relocation conditions permit, as shown in Figure 6. Take ShangXinJie station on Chongqing Rail Transit Line 1 as an example. The underpass on the west side of the entrance and exit of rail transit station 1 fails to connect with the roads on both sides. Pedestrians on both sides of the road need to detour to the signal intersection on the east side of the rail station to cross the street. According to the guidelines, break through the North-South block, connect the south-north direction of the underpass, and ensure the safety of pedestrian crossing, as shown in Figure 7.

![Figure 6. Example of Adding Pedestrian Cross-Street Independent Channels to Built Stations](image)
Figure 7. Example of Adding Pedestrian Cross-Street Independent Channels to Built-Stations

Make full use of the terrain features to set up the interchange crossing facilities at the entrance of the station on both sides of the main road. The new overpass is directly connected with the elevated station or the new underpass is directly connected with the underground station, so as to avoid the vertical detour of repeatedly going up the overpass or down the underpass, enhance the radiation range of the surrounding area of the railway station, and improve the travel willingness of pedestrian transfer. But at the same time, it should be combined with the project cost for comprehensive consideration.

5. Conclusion
Many plain cities in China have issued guidelines to guide the planning and design of urban rail station traffic connection, but mountain cities are lack of corresponding research and specifications. The particularity of terrain makes the traffic connection of mountain cities more complicated. Based on the redefinition of the actual walking distance, this paper explains the planning and design scope of the connecting facilities of rail transit station. From the perspective of pedestrian traffic psychology, taking the pedestrian connection around Chongqing rail station as an example, this paper analyzes the value of the guidelines in projects of mountainous cities. And it is proved that the "Chongqing rail transit station connection guidelines" has a guiding role in the new construction, reconstruction and expansion projects of other mountain cities.

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