

Study on Passenger Transfer Based on the Design of Underground Transportation Hub of Xi'an Railway Station

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Abstract: The current focus of traffic construction in China is the transportation hub. The building of modern, comprehensive three-dimensional (3D) transportation hubs plays a key role in the establishment of a modern transportation network. It is vital to consider factors like passengers and traffic circulation plan in the design of comprehensive transportation hubs. However, due to unreasonable design, problems such as inappropriate traffic circulations, the long transfer distance between various means of transportation and the complexity of transfer routes, emerge on occasion. To solve these challenges, taking the Underground Transportation Hub of Xi'an Railway Station as an example, this paper studies the design of comprehensive transportation hub from the perspective of passengers and the design of traffic circulations, and is expected to provide reference for the design of comprehensive hubs in the traffic field.

Keywords: Comprehensive Transportation Hub; Traffic Circulation; Transfer, Stream Circulation Design; Traffic Organization

Introduction

The 13th Five-Year Plan for the Development of a Modern Comprehensive Transport System states: The building of a number of modern and three-dimensional comprehensive passenger transport hubs will make passengers' transfer more convenient.

As an active attempt of "modern, comprehensive three-dimensional passenger transport hub", the Xi'an Railway Station Underground Comprehensive Transportation Hub is a large underground comprehensive transportation hub connecting high-speed railways, subways, buses, taxis, online hailing cars and private cars.

1. Key Points of Traffic Circulation

The key of organizing traffic circulations in transportation hubs is about management of various vehicles, analysis and arrangement of different traffic lanes. Therefore, the design should not only meet the needs of receiving and hauling passengers and parking various vehicles, but also can ensure safe and smooth traffic in the hub, especially to avoid the intersection of traffic circulations as much as possible.

The modes of transportation in the underground hub can be subdivided into: Passenger-hauling private car, passenger-hauling online hailing cars, passenger-hauling taxi, passenger-receiving private car, passenger-receiving online hailing cars, passenger-receiving taxi, bus at departure station, bus at intermediate station, etc., so the requirements of traffic flow vary among different vehicles. As a result, the design of each lane should be customized according to their characteristics. The circulation organization of various vehicles are as follows^[1].

- (1) Private cars to haul passengers: enter with passengers--passengers get off when stopping at the curbside platform--leave without any passengers.
- (2) Online hailing cars to haul and receive passengers: enter with passengers--passengers get off when entering the Online hailing cars park--wait for being hailed--receive passengers--leave with passengers.

(3) Taxis to haul and receive passengers: enter with passengers--passengers get off when stopping at the curbside platform--a or b.

a: leave without any passengers.

b: Return to the free taxi storage yard--receive passengers if there are passengers in the boarding area--leave with passengers.

(4) Private cars to receive passengers: enter without passengers--enter the park and wait--receive passengers--leave with passengers.

(5) Bus at the departure station: enter with passengers--passengers get off when the bus stops at the drop-off platform--enter the public transport parking place without passengers--receive passengers at the departure station--leave with passengers.

(6) Bus at intermediate station: enter with passengers--passengers get off when the bus stops at the drop-off platform--leave with passengers.

After sorting out the demand of traffic circulations, it is also necessary to merge and integrate various passenger circulations in accordance with the restrictions on land use in order to build a hub with intensive land use, reasonable circulations and complete functions.

2. Design of the Traffic Circulation for Underground Traffic Hub of Xi'an

Railway Station

2.1 Land Conditions of the Hub

The Underground Traffic Hub of Xi'an Railway Station is located between the Tang Daming Palace Ruins Park and the renovated and expanded Xi'an Railway Station, and its north side is 50 meters away from Danfeng Gate. It is about 120 meters wide from south to north and 1000 meters long from east to west. Considering the project is located in the south of the Daming Palace Ruins Park, in order to better protect this world heritage, the ground is designed as the Danfeng Gate Square just for pedestrians, and the transportation hub functions are all arranged underground^[2].

2.2 Horizontal Design of the Hub

Based on the analysis of vehicle circulations and various constraints, the project is finally designed to be an all-underground transportation hub with five floors underground.

The ground of the hub is Danfeng Gate Square of Daming Palace Ruins Park, which is just for pedestrians.

The underground is divided into five floors, and the functions are:

The first-floor underground is functioned as passenger-hauling. Passengers can reach the hub by various means of transport. After they get off, they can take escalators to the ground, where they are able to check in. It is equipped with curbside platform, intermediate bus station and bus terminal.

The second-floor underground is mainly used for receiving passengers, where they can leave the railway station by various vehicles. Passengers can go to the sunken transfer square on the second floor through the underground exit passage, and then choose a means of transportation to leave the commuter station. There is bus waiting hall, taxi storage area, taxi pick-up area, reserved subway entrances and exits, car parking garage, etc.

The third floor is a car parking garage. The fourth and fifth floors underground are reserved subway station halls and platforms^[3].

2.3 East-west Circulation Specification of the Hub

The project has two accesses on the east and west sides and there are four major types of traffic circulations, namely eastern bus circulation, eastern car circulation, west bus circulation and west car circulation. Buses run in the outer circle east-west, and cars run in the inner circle, forming independent double C-shaped passages east-west.

2.4 Bus Circulation

Buses on the west side enter the negative first floor through the access ramp. They enter the bus parking area after sending passengers off at the intermediate bus station and go to the west after picking up passengers at the departure station. The bus circulation on the east side is similar to that on the west side. East-west transit buses pass through the underground transportation hub, sending passengers off and picking up passengers on the intermediate bus station.

2.5 Taxi Circulation

The taxi enters the first underground floor from the entrance ramp, and can leave directly from the exit ramp after sending passengers off at the curbside platform. Or they can go down and wait in the taxi storage area on the second-floor underground, enter the taxi pick-up area, and go up to the floor underground to leave from the exit ramp after picking-up passengers. Circulations on the east side and the west side are basically symmetrically arranged [4].

2.6 Hailing Car Circulation

Hailing cars enter the first floor underground from the entrance ramp, then go to the car parking area from the ramp down to the second floor underground to send passengers off, and get into the parking space to wait for passengers. After being hailed, they pick up passengers and go up the ramp to the first floor underground and leave from the exit ramp. Circulation on the east side and the west side are basically symmetrically arranged.

2.7 General Vehicle Circulation

The drop-off Circulation (park temporarily and leave as soon as possible): general vehicles enter the negative first floor from the access ramp and leave from the exit ramp after passengers get off at the curbside platform.

The pick-up circulation (entering parking area): general vehicles enter the first floor underground from the entrance ramp, next go to the car parking area from the ramp down to the second floor underground to wait, and then get into the first floor underground through the ramp and leave from the exit ramp there after picking up passengers. Circulations on the east side and the west side are basically symmetrically arranged [5].

3. Key Points of Passenger Circulation Plan

The comprehensive transportation hub connects different means of transportation. Accordingly, the pedestrian circulations inside are various, so the space design of pedestrian circulations is far from a simple superposition of several elements, and it should be made in accordance with certain rules. Basic principles of the design include: clear structure; bus priority; separation of passengers and vehicles; reasonable design of space.

3.1 Clear Structure

According to the principles of Gestalt Psychology, people prefer to perceive the whole space through parts in isolation. To be more specific, facing a complex space, people prefer to consider it as a common, known, complete space for better understanding. Therefore, the complex structure of the space will make new passengers lost, resulting in erroneous judgments.

A space with a clear structure should be clean and uncluttered, where passengers are familiar with its functional zones and can understand it quickly. So, they can instantly identify and choose the transfer passage in this condition [6].

3.2 Bus Priority

As a transportation building used by the public, comprehensive transportation hubs enjoy a public attribute in nature that also owned by cities, so it's necessary to comprehensively consider the needs of different groups. In the arrangement of traffic stations, it is essential to place them from near to far according to their public characters.

3.3 Separation of Passengers and Vehicles

The principle of passenger-vehicle separation is the key to ensure passengers' safety and improve the transfer efficiency. The transportation hub building is inherently complex, where vehicles are running intensively. If passengers and vehicles are not separated and jumbled together, it is prone to accidents, because factors such as passengers moving cross the road, and vehicles stopping to wait and pick up people, will reduce the operation efficiency of the hub.

3.4 Reasonable Design of Space

A transportation hub is a building with a large flow of people, so it calls for sufficient space. However, restricted by investment, land, specifications and so on, the design cannot be over-sized, so it is very important to accurately calculate the area or length of each part in the space^[7].

4. Design of Passenger Circulation for Underground Traffic Hub of Xi'an

Railway Station

The Underground Hub of Xi'an Railway Station is designed according to the four basic principles of "clear structure, bus priority, separation of passengers and vehicles, reasonable design of space". Its characteristics are as follows:

4.1 Clear Structure and Bus Priority

The Underground Hub of Xi'an Railway Station is equipped with entrances and exits in each floor. According to the design concept of Xi'an Railway Station that "entrance on the ground floor, while exit underground", the first floor underground of the hub is designed for passenger-hauling with curbside platforms, intermediate bus stations and a bus terminal. Passengers arrive at this floor by means of transportation. Then they can get off and enter the railway station through the escalator on the ground.

The first-floor underground is designed in the manner of "independent and distributed pattern" without a hall for massive transfer. The pedestrian platform is independently arranged between the traffic lanes like an "island". Passengers go directly to the ground through the escalators in their respective islands and enter the railway station together in the ground concourse. This design not only meets the demand of the length of the curbside platform of different vehicles, but also avoids the intersection of passengers and vehicles.

The second-floor underground is for picking up passengers, which has the same elevation as the exit passage underground of the railway station. Passengers arrive at the hub from the exit passage underground of the railway station and then leave by various means of transportation there. There is bus waiting hall, taxi storage area, taxi pick-up area, reserved subway entrances and exits, car parking garage, etc. [8]

The second-floor underground is designed by the "concentrate dispersion" pattern, and passengers are distributed into various traffic stations step by step following the principle of "bus priority". The mode at the first level is pedestrian traffic, passengers of which are directly diverted in the sunken transfer square, where they can see the escalator on the ground. The transfer distance is 50 meters, and the transfer time is less than 1 minute. The bus and subway that with the strongest public character are at the second level. Their entrances are close to the transfer hall, and passengers can notice it immediately upon entering the hall. The transfer distance is 90 meters which takes about 1 minute to go. At the third level, there is the taxi, which is next to the bus and subway in terms of its public character. The transfer entrance is connected with the transfer hall through a short channel. The transfer distance is 110 meters and the time is about 1.5 minutes. At the fourth level, there are the online hailing car and private car with the weakest public character. The transfer distance between the connecting passage of the transfer entrance and the staircase of the building is 200 meters, and the transfer time is about 2 minutes.

4.2 Separation of Passengers and Vehicles

The design takes three methods of "plane separation", "same-floor interchange" and "hierarchical interchange" to separate passengers and vehicles.

The plane separation means to use the platform and railings of 150mm (car) and 200mm (bus) higher than the lane to divide the semi-independent safety space of the whole pedestrian, in which passengers and vehicles cannot cross the boundary at will, so they are separated. At the same time, the safety of passengers and the efficiency of vehicle passage are guaranteed^[9].

The same-floor interchange is used when intersections of passengers and vehicles happen frequently. The pedestrian interchange in the space on the same floor enables passengers and vehicles to cross, and the space is divided into an upper part and a lower part. This mode is used in the passenger loading area of taxis, where the passengers go up and down the pedestrian interchange through a ramp, and the taxi passes under the interchange bridge. Therefore, they are completely separated.

The hierarchical interchange organizes passengers and vehicles with the upper and lower floors. This mode is used in the bus pick-up island. Passengers can identify the bus they are going to take on this floor and then reach the bus pick-up island on the upper floor by escalator, and buses pass on the upper floor.

Conclusion

The comprehensive transportation hub is a kind of multi-functional transportation building. Its design is complex, among which the passenger and vehicle circulations design is the key to its whole construction^[10].

The crucial point to the design of vehicle circulation is that the circulation itself is simple, and different circulations won't be crossed. While the key point to the design of pedestrian circulation is clear separation structure, bus priority and avoidance of crossing between passengers and vehicles.

Following the basic principles of passenger and vehicle circulations design, and taking the Underground Transportation Hub of Xi'an Railway Station as an example, this paper analyzes the transfer design of comprehensive transportation hub, and suggests feasible modes, which provides reference for the design of comprehensive hubs in the traffic field.

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