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Research of non-motor vehicle-rail transit-tube interchanging transport system pattern

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ABSTRACT: In the light of the relationship between land use and rail transit, it considers that the development of the public transport is one of the effective ways to solve the problems in traffic. Urban rail transit that can lead the development of the cities should be the backbone in the public traffic. This paper presents the research about non-motor vehicle-rail transit interchanging transport system patterns. The interchange pattern is proved to be feasible by investigation and calculation research. The purpose is to make public transportation more effective, and elevate the leading role of rail transit. The paper also indicates the effective ways to solve the problems in traffic in order to exalt the proportion of the urban rail transit.

1 GENERAL INTRODUCTION

Nowadays, there are many researches about the interchange of rail transit and public transportation (such as airport, railway, subway) along with the increasing urban rail transit lines in Beijing and Shanghai etc. However, these researches hardly mention the interchange of non-motor vehicle traffic to rail transit. Through the investigation on general distribution station (refers to the station around the inhabited area, public transportation, non-motor vehicle and walking system primarily), this paper presents the research about non-motor vehicle-rail transit interchanging transport system patterns. The purpose is to facilitate the public transportation, and elevate the leading role of rail transit. With the development of rail transit network, it is very important to investigate the model of the affected factor in station and the land use around to provide a comfortable, safe and convenient environment in transit interchanging. The paper proposes the effective ways to solve the problems in traffic, in order to exalt the proportion of the urban rail transit.

2 THEORY OF THE LAND USE AROUND THE RAIL TRANSPORT STATIONS

The fundamental characteristic of the railway station can be summarized as the following: forming the buildings around the railway station, which generate the core-axis pattern, developing the traffic organization and function layout with the center of railway station. Land is important to a city, and reasonable use of land will do benefit to the economy, society as well as the ecosystem. The aim of land use shows complex, multidimensional and integrative in space form, which request close cooperation between infrastructure development and civil development to optimize land use. In the range of railway station, it should be emphasized of the relation and merge between different city functions, which can make people enjoy the use of railway and embody the theory of "people oriented".

In developed countries, some new urban planners break through the limit of the traditional urban planning theory under the city's sustainable development background, and proposed Transit-Oriented Development Model, i.e. TOD Model. It is expected the use of public transport to lead the development of a city, and back to the model of using bicycle and walking. The main content of TOD is: Using public transportation station as a center, walking distance as a radius. In this area, high density of the land use is emphasized and public transportation facilities are arranged around station. By walking, bicycle and public bus etc, high effective interchange to replace the leading role of car in city.

Because of the diversity between China and west developed countries on population density and city development stage, there are some differences of using TOD theory, explained as follows:

1. Different background: After the World War II, the cars become popular in cities of US, the energy

waste becomes serious, suburbanization and urban blight of the city downtown. The TOD concept was right proposed under this background. But cities in China are still in highly development. The main problem is how to develop public transportation, to solve the traffic jam carried up by high density of city's population and deterioration of the environment.

2. Population density: In US, low population density, and the main transportation home-based-trips are cars used. But in China, population density is higher. Even the residential area in suburb, the population density is still higher than foreign country.
3. Willingness to use public transportation: Because of the distributed suburb, high percentage of people owing cars and more highways, the public transportation has less attraction to publication in western countries. But in China, it is because of the large population, short of effective facilities, and undeveloped construction technique and management technique that there always exits the traffic jam, lower speed of transportation and lack of comfortable conditions. There will be a vicious circle along with the more cars using.
4. The difference of influence radius of station: In foreign TOD model, there are a 600 meter influence radius with the center of the station. And the interchange with rail transit is most based on walk system. But in China, the density of rail transit network is lower, instead of higher population density, and the influence radius of railway station is larger, people use interchange mostly by public bus and bicycle etc with rail transit, which makes the interchange pattern of the railway station and surrounding area different.

It can be seen from the operation of foreign big cities' transportation that the percentage of railway passenger is 45% to 60% to the total one. But in China, the percentage of bus makes over 75%, and that of railway is much lower. It is because that the development of rail transit transportation is on the beginning, and hasn't formed a transport net. The density of station and network is over 1500 km in London, New York, Paris and Tokyo, and there is a high railway density in down town also. The density of railway and stations in town is shown in Table 1. It will generally take 5 to 10 minutes for people walking from home to the railway station. Take Beijing for example, the density of subway in down town is only 0.32 km/km^2, which is one tenth of that compared to developed countries. It is pointed out in literature that the downtown district, middle district and outskirt district of a big city can be taken as 1.6, 0.8 and 0.4 km/km^2 based on China's situation and it is found acceptable. It is still a gap of the density of the railway system with developed countries.

Table 1. The density of station and network in London, New York, Paris and Tokyo.

	London	New York	Paris	Tokyo
Density of network km/km^2	3.49	3.47	3.76	2.6
Density of station unit/km^2	2.52	3.92	4.58	1.59

In conclusion, due to low network density in china, the application of TOD model in China's cities will be modified as: it should be based on the station as a center, rail transit, bus and non-motor vehicles as an interchange for development. The main task is not to increase the residential density but how to combine land use and public transport together, which can provide a comfort, convenient and attractive public transport system. By doing so can we make use of the network effectively as the backbone in city's development.

3 RAIL TRANSPORT SYSTEM PATTERNS IN DIFFERENT CHARACTERISTIC STATION

To different railway transportation types of stations (It is classified into large scale interchange station, general interchange station and general distribution station) area, accordingly there are different major functions (seen in Table 2). Generally, for station in downtown area (large-scale interchange station or general interchange station), the commercial business development area consist up the majority of this district, and the residential development area takes up the minority of this district. For station in outskirt or newly developed area (general interchange station or general station), the most suitable development in this area should be residential development.

In planning the station and surrounding area, the main concern point should be the land use around the station. For example, in city CBD area, the station should be built as the commercial center of, especially in interchange station of multi-trip railway lines. The underground space exploitation should also be considered to develop a district, which is incorporating transportation and business or other functions to form an underground urban complex.

For interchange station in outskirt of the city or in development zone, it should be considered together with other transport method e.g. private cars, buses, non-engine cars.

For stations at suburbs of the city, the majority method of interchange is using Cars Peripheral Park and Ride (P&R). The P&R refers to the interchanging facilities for people in outskirt parking cars around the railway station or public transportation's end stop. By using public transportation system to down town, the

Table 2. Classification in different rail transit station.

	Classification in different rail transit station	Land use around station	Different interchange forms
Rail transit station	Large-scale interchange station	Town center commercial circle and CBD area	Within rail transits (3 or over 3 lines)
		City suburb	Rail transit with air plane
		City distribution center	Rail transit with railway Rail transit with Road passenger transportation
		commercial area and residential district	Rail transit with public transport
	General interchange station	City sub-center	Within rail transits (2 lines) Rail transit with public transport
		Development zone	Peripheral Park and Ride (P&R)
	General distribution station	Residential district	Rail transit with public transport Rail transit with non-motor vehicle Rail transit with walk system

use of private cars in down town area is decreased. The outskirt interchange facilities are the link of cars and public transportation system. It major function is to provide the effective, safe, convenient, comfortable linkage between outskirt cars system and downtown public transportation system, so as to increase the attraction of the public transportation system and decrease the use of cars in down town area. By doing so, the transportation pressure in down town area could be diminished and realize the sustainable development of the city's transportation system. This method is suitable for outskirt of the city. The railway station must provide the sufficient parking facilities, parking lots to meet the interchange need. The parking facilities must be near to the station, and have connection path to the station. The enough roads should be planned and constructed.

Regarding in urban general distribution station, preceded by text analysis, the main consideration is the walk system, the non-motor vehicle transportation system and the bus, the taxi convenient interchanges.

The walking system is the most primary connection with the rail transit, the content mainly includes sidewalks system in station, the facility and the passengers separates from vehicle facility plan design, the guidance informational sign design, walking routes organization design and so on. Therefore the walking system should be given priority in rail transit design. Considered transportation station around the land use intensity is high, passengers activity is also frequent, and in order to increase commercial stores suitable sidewalks should be provided. Traffic island and crosswalk must be considerable and designed in this area. The walk system in the station which connect platform meets the convenient needs in the station, but also achieve the evacuated request, simultaneously also must have distinct guidance symbol.

The bicycle is one of effective ways connected with rail transit also. Enough bicycle parks should be provided in joints of station design, appropriative parking zone be setting which is connected with underground tunnel, accommodation road should be constructed in order to lower the effects from non-motor vehicle in traffic.

The interchange between bus transportation and rail transit mainly includes the roadside parking pattern, parallel pattern, vertical pattern and centralized pattern. Bus accommodation road can be presented and the bus stop should be built near subway station' entrance-exit which can provide comfortable, safe and convenient environment in transit interchanging.

4 RESEARCH OF NON-MOTOR VEHICLE-RAIL TRANSIT-TUBE INTERCHANGING TRANSPORT SYSTEM PATTERN

Bicycle is one of the effective manners in public traffic. Especially in china at present, inferior service in public traffic, undeveloped mechanization. Bicycle shows cheap, convenient and unpolluted characteristics, it takes important status in our country public traffic. The interchanging content mainly includes bicycle park system in station, the facility of the passengers separates from vehicle facility planned and suitable routes organization designed near the station.

Bicycle-rail transit-tube transferring transport system patterns design should follow principles:

1. The interchange pattern is suitable in the city suburb or in residential district around rail transit station (General in distribution station), and it can be not applied in city center.

2. In order to avoiding occupying of the space, decrease the effects to the transport, it should provide enough quantity if the bicycle special parking spots.
3. Appropriative bicycle parking lots on the ground should be provided near the station which passenger flow is large, and passengers may take interchange through tunnel; dispersed bicycle parking zone may be designed around the station which has few passenger flow, yet is not so closed to the station' entrance-exit in order to avoid effecting passengers.
4. In park essential facilities must be supplied and should arrange the specialist to manage with inexpensive charge.
5. To display bicycle superiority in short-distance home-based-trips, and limits its proportion in long-distance home-based-trips. Reasonable bicycle routes and accommodation road system can reduce the bicycle' effects in traffic and provides comfortable, safe and convenient environment in transit interchanging.

In general distribution station, which interchange with rail transit almost are public traffic (bus) and non-motor vehicle (such as automobile, bicycle and walk system). At present in many stations usual show: bicycles are laid on the street or some temporary open-air non-motor vehicle parks spot all around, it has occupied the limited station' space. Simultaneously the bicycle around the station may on the passenger 'way, hinder the pedestrian traffic, and potential security risk exists also. Although many stations peripheral non-motor vehicle parks have take specialists, accommodation tunnel which may connect rail transit and bicycles are not been designed. It enlarges interchanging distance, takes inconvenient and lowers the interchanging efficiency.

Based on the interchange principle between non-motor vehicle and rail transit introduced above, it is proposed in this paper the Bicycle-rail transit-tube transferring transport system patterns concept by using a general underground subway station as an example.

For a general station, the length is about 200 m, the width is about 20 m (30–35 m if including exit). Four exits are designed on both sides of the station, and are constructed in conjunction with the ventilation shaft etc affiliates as shown in Figure 1. The station is situated under the cross, and four exits are situated at four corners of the road. In construction of the station, the main structure will be constructed first, and then the exit. It can be seen from the plane layout that the two exits in the same direction would be constructed separately, and no connection between the two exits. The shadow area in the middle has no use. If it can be constructed at the same time with the exits of the station, the two exits and the middle part could form the underground parking bicycle etc. By doing so, the land around the station can be used intensively, and

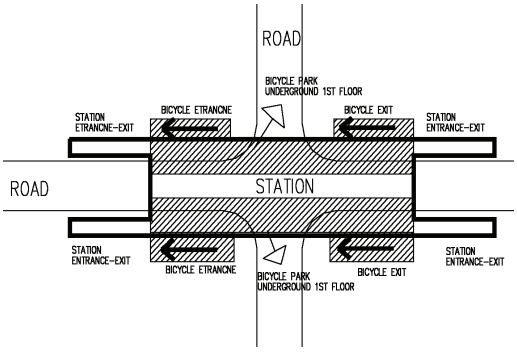

Figure 1. Bicycle-rail transit-tube interchanging transport system patterns in General distribution station on the 1st flood underground.

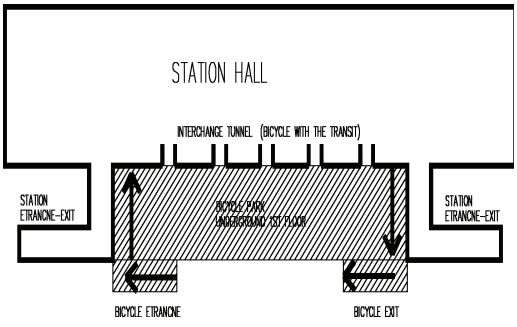

Figure 2. Sketch map of Bicycle parks underground.

decrease the station ground area occupation area and passenger flow on the ground. The phenomenon of scramble between bicycle and car will be decreased, and the interchange efficiency of non-motor vehicle and railway will be highly increased.

The underground non-motor vehicle is shown as shadow area in fig. 1, the four corners of the road could be set as bicycles parking exit (shown in Fig. 2) which makes the passengers from both directions can park their bicycles effectively and interchange with rail transit (interchanging may use the mutual wall between station hall and bicycle parking area or use tunnel). For consideration of parking area of bicycle, this shadow area is about one third of the station main area (about 60 m) with the width of 20 m, area of 1200 m^2 (total area 2400 m^2). The major design reference can be planed by Bicycle Parking Design Standard.

The principle factors considered for the scale of a normal park for bicycles include the number of bicycles reaching to station, the area occupied by one bicycle, and the piece of the bicycle park. According to the piece, the scale of the bicycle park can be calculated as following:

$$S_{bic} = s_{bic} V_{bic} / \lambda_{bic} \quad (1)$$

Table 3. The main design index in bicycle park.

Parking type		Parking width single (m)	Parking width double (m)	Space between bicycles (m)	Aisle width single (m)	Aisle width double (m)
Diagonal	30°	1.00	1.60	0.50	1.20	2.0
	45°	1.40	2.26	0.50	1.20	2.0
	60°	1.70	2.77	0.50	1.50	2.0
Vertical		2.00	3.20	0.60	1.50	2.0

Parking type		Unit area Single one-side m^2	Single two-sides m^2	Double one-side m^2	Double two-sides m^2
Diagonal	30°	2.20	2.00	2.00	1.80
	45°	1.84	1.70	1.65	1.51
	60°	1.85	1.73	1.67	1.55
Vertical		2.10	1.98	1.86	1.74

where: S_{bic} denotes the needed scale for bicycles in the station (m^2); V_{bic} is the number of bicycles during rush hour piece/hour); λ_{bic} is the velocity of the bicycle park; s_{bic} is the averaged area occupied by a bicycle (m^2).

The velocity can be set as 1 due to little change of the number of bicycles because the users of the bicycles in the station are almost only to work or back from work by bicycles. The area occupied by a bicycle, obtained from Table 3, is 1.7 m^2. Through calculating, the capacity of the underground bicycle park, excluding the public area, is 1200 units.

Through the sampling survey of numbers of bicycles near the available stations in Shanghai rail transit carried out by the author, the following point are given: the number of persons using bicycles for interchanging transportation, including the persons who arbitrarily lay their bicycles at the edges of road or near some shops, is about 800 to 1000. According to the above results, it can be seen that the capacity of the underground park area in a normal station can meet the requirement of paring bicycles for transportation interchanging.

For the station of main body lay on the side of road, the underground park area for bicycles can be set up as shown in Figure 3. For this type of parking area, the ceiling can be mounted by transparent materials for accessing of sunlight. The vegetable processing on the top of the park will improve the inner environment in an extent through the hole between the parking area and station hall.

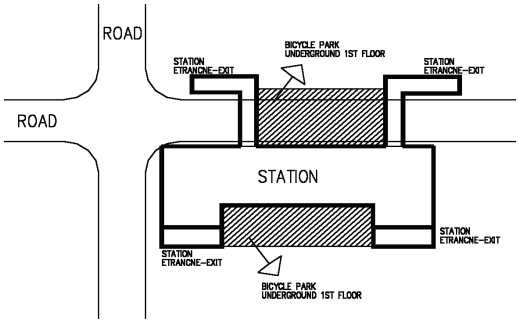

Figure 3. Sketch map of Bicycle-rail transit-tube interchanging transport system patterns (station on one side of road).

Taking the variety of the plane layout of the railway transportation stations into accounting, the underground parking area for bicycles combined railway station, proposed in this paper, is a conceptual pattern. The exact arrangement will be adjusted according to the actual plane layout of stations. The principle idea of the model is to efficiently utilize the area near the entrances and exits, realize the interchanging between bicycles and railway transportation without extra cost, and increase the efficiency of interchanging.

For the underground parking area of bicycles in a station, the construction is feasible in techniques. In general, the stations which need this type of parking area are in the sub-center, outskirt or near the satellite city. The main buildings near the stations are residential districts also, the construction of the station will almost not affected by the environment around. The parking area can be constructed with the main structure of the station by open excavation method in foundation. Also, it's feasible to firstly construct the main structure of the station and then construct the parking area combined the entrances and exits by open excavation method or top-down method.

5 CONCLUSIONS

Through the analysis above, it can be concluded that the underground bicycle parking area for transit interchanging is feasible in reality. The advantages as below:

1. The users of bicycles can interchange rail transit through the entrance between the under ground parking area and station conveniently, which realize the interchange without extra cost, increasing the efficiency in a great extent, providing the comfortable environment in transit interchanging at same time and expressing the conception of people oriented.

2. The underground interchange between bicycle and railway transit decreases the occupied area of the station, facilitate the travelers using other types of transportation which transfigure the environment around the station.
3. This pattern of transit interchanging can decrease the flow of bicycles on the ground, increases the efficiency of motor passing, eliminates the possibility of traffic accident and realizes the Pedestrian System Separated from Vehicle System by passenger interchanging through tunnels.

The cost of construction for the underground bicycles parking area is higher than normal station. Nevertheless, synthetically considering the Traffic Diversion on the ground, the effect on the passenger flow by other patterns of transportation, and the environment near the station, the society and economic benefit resulting from what it brings will exceed far from what it costs.

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