Planning of inter-city transfer networks in Weifang City

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Abstract: the inter-city passenger flow and travelling patterns in the inter-city transfer networks in Weifang City were explored. Based on prediction of the traffic needs of the network, this study explored the optimization model of inter-city transfer networks and the planning of transfer hubs. The objectives of this study are to optimize the structure of transfer networks and improve the efficiency of inter-city traveling.

1. Introduction
As a major means of inter-city transportation, rail transit has a travelling chain that can be divided into the point of departure, the rail transfer hub, inter-city rail transit bus terminals, etc. Lots of studies in China and abroad have probed into inter-city transfer networks. Nurul Habib explored the traveling features of the Great Toronto Area using the system model [1]; Dargay pointed out that income, gender and age have much impact on the travelling distance [2]; Gelareh studied the locationing of transfer hubs using mathematical models [3]; Spring constructed a transfer schedule connection model [4]; Cao built a model for evaluation of the efficiency of transfer hubs [5]; Liu proposed suggestions to optimize the inter-city railway networks [6]; With the inter-city transfer network in Weifang City as a study case, this study analyzed the features of inter-city passenger flow, and based on prediction of traffic needs, explored the planning of inter-city transfer hubs that conforms to China’s realities in hopes of providing a theoretical basis and experience to optimize the structure of transfer networks and improve the efficiency of inter-city travelling.

2. Investigation methods for inter-city travelling
The downtown area of Weifang covers an area of 115 km² and has a population of 1.4 million. With the West Outer-ring Road, the Bailang River, East Ring Road, Jinan-Qingdao High-speed Railway, North Outer-ring Road, Jinan-Qingdao Highway, East-West Health Street, Jiaoji Railway, South Outer-ring Road as the boundaries, this area is divided into nine traffic regions, which are taken as the study object here.

We suppose that the daily inter-city passenger flow is 10,000, and thus the standard deviation of the inter-city travel density is 3 persons/km². According to the size of the samples:

\[ z = \frac{10000}{\sqrt{3000}} \]

where

\[ z \] – the confidence level of the standard deviation. The confidence level of this study is 90%, and the corresponding z value is 1.67;
\( \sigma \) — the overall standard deviation, which is determined as 3 here; 
\( e \) — the acceptable sampling error, which is 15\% here.

The total number of the samples here is 1000.

At the end of June, 2018, 30 investigation members distributed questionnaires in the waiting halls of Weifang Railway Station to passengers bound for Zibo, Qingdao, Yantai, Weihai and other cities. 1,026 questionnaires were collected, of which 1,009 were valid and met the requirements.

### 3. Analysis of features of investigation samples

Among the passengers, 33\% were departing from Weifang and 67\% were from other cities, indicating the close connection Weifang had with other cities, and the railway station served as a major channel of inter-city people exchange. Analysis on the origin of the samples (passengers from and bound for cities outside the city group on the peninsula were not taken as the study subjects) shows that most of the passengers were from Qingdao (about 50\%), the reason for which might be that Qingdao and Weifang is close both in distance and geopolitic relations; the second largest group of passengers were from Jinan and Zibo (about 32\%), indicating the strong radiating effect of these two cities as the two kernels in the city group. The analysis of these sample cities shows that about 60\% of the passengers were passing by Weifang instead of taking Weifang as the destination or departing place, which reflects the role of Weifang as the traffic transfer hub and a connecting city in the city group of the peninsula.

Among the sample passengers, 81\% were below 35 years old, most of whom were between 18 and 35. Within this age range are students at school and the major workforce, who takes up the largest proportion in the samples, reaching 80\%. Analysis of the professions of the samples shows that the three top professions were enterpris managers, technicians and students (68\%), which is consistent with analysis results of investigation in other cities. Analysis of the industries that the samples belong to shows that the top three industries were manufacturing, education and research and the IT industry (around 50\%), which are three of the dominating industries in Weifang and cities on the peninsula, while the population for other industries was similar. Most of the sample passengers had an annual income less than 100,000 (58\%), and those with an annual income of 60,000 ~ 100,000 reached 34\%, which was consistent with the structure of annual income of people on the peninsula.

Analysis shows that most passengers travelling between cities and Weifang were for business trips, which indicated the low rate of inter-city commuting caused by home-office separation, and this is closely related to the economic conditions of cities in the peninsula. Most inter-city commuters there live in Weifang and work in Jinan and Qingdao; moreover, the proportion of travelers for recreational purposes was high, and the major destinations were coastal resorts like Qingdao, Yantai and Weihai. Analysis of the travelling frequency by travelling purposes shows that the average traveling frequency for work was 1.08/month, that for study was 0.98/month, and that for business trips was 0.90/month. This shwoes that the number of passengers for business trips was large and had high frequency of travelling, accounting for the major type of travelling among cities on the peninsula.

### 4. Research on inter-city transfer networks

#### 4.1 Analysis of inter-city transfer

GIS spatial analysis shows that the departure places and destinations for travelers in Weifang are in the downtown and other places with high population densities, which are encircled by the Jiaoji Railway, Jinan-Qingdao Highway and Bailang River. Therefore, the probability of inter-city travelling density is positively correlated to residential population density.

The major means of transportation for passengers include taxi, bus and private cars. 85\% took public transporation means, and 44\% took bus, which reflects the convenient bus and railway network in Weifang; 70\% of the buses in Weifang can reach the railway station, and passengers can reach the railway station by two transfers at most, and the average number of transfers is 1.2. In terms of the length of travelling, travelers take 35 minutes by bus, 23 minutes by taxi and 8 minutes by foot before
reaching the destination; while the expected travelling time for bus travelers is 21 minutes, which shows that the bus network still needs improvement.

The inter-city transfer network is dominated by buses. There are 13 buses and several fast transfer hubs, with Weifang Railway Station as the central transfer hub, creating a “seven in one” inter-city travelling network that connects the downtown, Weicheng, Kuining District, Fangzi District, Haiting District, the Economic Zone, and the High Tech Zone, which improves the transportation efficiency with other cities on the peninsula. The study found that the concentration pattern of departure and destination sites for inter-city travelling in Weifang is consistent with other city groups, which indicates the spatial connection between inter-city travelling and layout of urban functions.

4.2 Prediction of inter-city passenger flow

Weifang is an important transport link between Jinan and Qingdao, a transport hub where Jinan-Qingdao Highway, Jiaozhou-Jinan Road, Jiaozuo-Jinan Railway, Qingdao-Yinchuan Highway, Rongcheng-Weifang Highway, Weifang-Rizhao Highway and many other railways and highways passes through. Weifang Station is a major hub on the Jiaozuo-Jinan passenger line, and Weifang North Station is an intermediate station on Weifang-Rizhao Railway Station, and Weifang East Station connects Longkou-Yantai-Weihai High-speed Railway and Weifang-Rizhao Railway.

Among inter-city travelers, most are bound easternward for Qingdao, westernwards for Jinan and Zibo (about 70%), and others are for secondary central cities including Rizhao, Yantai, Weihai and Binzhou. It is predicted that by 2030, the total passenger flow will reach 600 million, and the outbound passenger flow will reach 60 million. The traffic route planning shows that Jinan and Qingdao remain the major destinations, the Jiaozhou-Jinan Express Way and Qingdao Rongcheng Railway will undertake 55% of the passenger flow, and the Jinan-Qingdao High-speed Railway will undertake 45%.

By 2030, the annual passenger flow in Weifang will reach 164,300, with 15~20% during the rush hours. If the rush-hour passenger flow is 30,000, the passenger flow in Weifang Station, Weifang North Station and Weifang East Station will be 13,800, 11,200 and 5000. The inter-city transfer hubs should be arranged according to the demand and density of inter-city travelling to reduce the resistance against transfer and improve the efficiency of inter-city travelling.

An optimal distribution model that based on the minimum travelling time of the total social distance is established.

This model distributes the passenger flow during the rush hours of workdays in 2030. The distribution has two types: the first is to set inter-city transfer stations, the other is not setting regional transfer stations. With the transportation of a community in the downtown as the study case, the average intra-city travelling time is calculated. The coverage rate of rail transport in the community in the future will reach 20%, the coverage rate of the main buses will reach 70% and that of the bus network will be 100%. The average time to the community by bus is 18.4 minutes, while the average travelling time of a bus is 35 minutes, and the expected reaching time is 21 minutes. Therefore, setting inter-city transfer stations can reduce the frequency of transfer and improve the speed of delivery and transportation.

5. Conclusions

For cities with inter-city rail transport means, the high time consumption for inter-city travel is because of the weak connection between bus transfer hubs and stations. Bus transfer hubs and bus networks are built to meet the needs of intra-city transportation, and the methods and planning do not consider the coordination with inter-city transport stations. Relevant studies show that the travelling scale of inter-city transit will surge in the future, and building inter-city transfer stations will improve the efficiency of inter-city travelling efficiency. As many traditional transit stations serve intra-city travelling, these stations should be upgraded, such as introducing inter-city ticketing machines that allow integration of intra-city and inter-city traveling. Moreover, the inter-city traveling needs should be considered and connecting stations for branch bus networks should be preserved to expand the service coverage of inter-city travelling transfer stations.
Fund Project
1. National key research and development projects during the 13th five-year plan period "Classification and spatial optimization of village and town communities" (2019YFD1100801); 2. Soft science research project of the ministry of housing and urban-rural development "Research on the layout planning of residential and living facilities based on industry orientation – Take Jinan high-tech zone as an example"(2015-R2-023).

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