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Importance Analysis of Urban Rail Transit Network Station Based on Passenger

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ABSTRACT

Current urban rail transit has become a major mode of transportation, and passenger is an important factor of urban rail transport, so this article is based on passenger and the degree of the road network structure, calculating the point intensity of stations of urban rail transit, and then reaching a station importance by integrating many point intensities in a survey cycle time, and getting the station importance of urban rail transit network through concrete examples.

Keywords: Station Importance; Point Intensity; Passenger Urban Rail Transit Network

1. Introduction

Urban rail transit has been a rapid development in Chinese major cities, which is as the primary solution to solve urban congestion ills. After years of the development, it has gradually formed a network of urban rail transit operators in large cities such as Beijing, Shanghai, Guangzhou and others. Under the network operating, the station traffic, section traffic and so on, important operational indicators are used to reflect the operational status of rail, and provide an important basis for the organization and management. The station is the key of rail transit operations management, which is a key link in the process operators, and it protects the city rail premise security and stability operations, and how to efficiently run the station hierarchical management is the premise to guarantee urban rail security and stability operation.

However, there is only a qualitative analysis in traditional hierarchical management approach of the station and no dynamic variation is from the station's passenger quantitative grading. Therefore, this paper proposes a dynamic quantitative classification method based on the station passenger, providing the basis for the station operators under the conditions of the road network management and operation organizations.

2. Basic Concepts

2.1. Road Network Model

Drawing on the idea of the graph theory [1,2], the road network model is defined by consisting of several nodes, the directed edge and the right, which is abstracted the physical network of the actual operation in urban rail transit. As is shown in **Figure 1**, and **Figure 2** shows the actual operation road network of Beijing urban rail transit.

In **Figure 1**, $L_1, L_2, L_i, \cdots, L_n$ mean the line representing the spatial relationship of the section in the road network; the node S_{ij} means the station j in the corresponding i line in the road network.

2.2. Basic Concepts

Introduced concept of the degree on the basis of the above model, the degree of the node S_{ij} is the number of the edges associated with S_{ij}, denoted as $d(s_{ij})$. The following is given based on the concept of the degree of a node definition [3]:

Node: a point S_{ij}, if $d(s_{ij}) \geq 1$, then the point S_{ij} is the node.

Key nodes: a point S_{ij}, if $d(s_{ij}) \geq 3$, the point S_{ij} is the transfer node. Here, it refers to the transfer station and the greater impact on the node Passenger Route Choice.

Point of strength: the station operational process safety important degree, which is not only related with the station node (station connecting edges), but the amount of inbound and outbound under the urban rail transit network diagram.

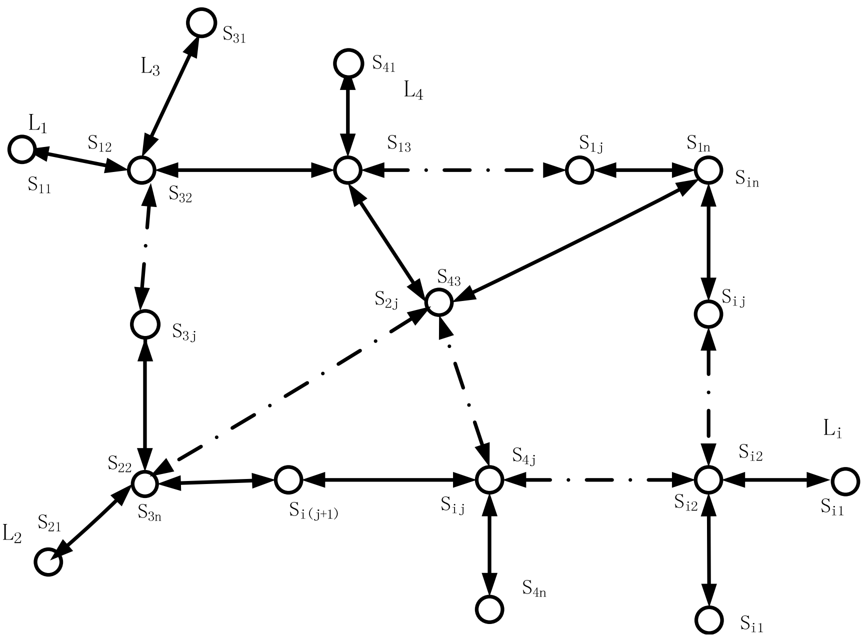

Figure 1. The urban rail transit network model.

3. Station Important Degree Research

The station importance refers to the influence extent of a station for the road network operational safety. The greater station importance indicates that the more important in the road network.

3.1. The Points Strength Calculation

According to the spatial and temporal characteristics of urban rail transit [4], the point strength of each station is different with the change of time and space [5], and reflects the dynamic changes in the station weight. When a security elements affecting the station security operations, the greater point intensity, the greater the impact on the whole line and road network [6]. The station j point strength in the time period t can be expressed as follows in the urban rail transit network model:

$$k_t\left(s_{ij}\right)=d\left(s_{ij}\right)\cdot\frac{c_t^{in}\left(s_{ij}\right)+c_t^{out}\left(s_{ij}\right)+c_t^{tc}\left(s_{ij}\right)}{\sum_{j=1}^{m}\left(c_t^{in}\left(s_{ij}\right)+c_t^{out}\left(s_{ij}\right)+c_t^{tc}\left(s_{ij}\right)\right)} \tag{1}$$

where: $d\left(s_{ij}\right)$ is the degree of the station j; $c_t^{in}\left(s_{ij}\right)$ is the input volume of the station j; $c_t^{out}\left(s_{ij}\right)$ is the output volume of the station j; $c_t^{tc}\left(s_{ij}\right)$ is the transfer volume of the station j.

3.2. The Station Importance Calculation

Due to the point intensity changes with time and space, the station point strength research in a statistical cycle of the road network. The station importance is based on the station point strength with time and space, which specific is as follows:

Assuming that there are m stations in the road network, and the statistical period T is divided into n time periods for the station j respectively $t_1, t_2, t_3, \cdots, t_n$, corresponding to the point of strength are

$$k_{jt_1}, k_{jt_2}, k_{jt_3}, \cdots, k_{jt_n},$$

then, the m point intensity matrix in a statistical cycle is shown:

$$\begin{pmatrix} k_{1t_1} & k_{1t_2} & k_{1t_3} & \cdots & k_{1t_n} \\ k_{2t_1} & k_{2t_2} & k_{2t_3} & \cdots & k_{2t_n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ k_{mt_1} & k_{mt_2} & k_{mt_3} & \cdots & k_{mt_n} \end{pmatrix} \tag{2}$$

If the station in and out passenger are

$$c_{t_1}, c_{t_2}, c_{t_3}, \cdots, c_{t_n}$$

during the statistical cycle of n periods, the total traffic is

$$C=\sum_{x=1}^{n} c_{t_x},$$

and the weight coefficient matrix of the station in and out traffic is

$$\begin{pmatrix} \frac{c_{t_1}}{C} & \frac{c_{t_2}}{C} & \frac{c_{t_3}}{C} & \cdots & \frac{c_{t_n}}{C} \end{pmatrix}.$$

If the m stations importance degree

$$Z_1, Z_2, Z_3, Z_4, \cdots, Z_m,$$

then

$$\begin{pmatrix} Z_1 \\ Z_2 \\ Z_3 \\ \vdots \\ Z_m \end{pmatrix} = \begin{pmatrix} k_{1t_1} & k_{1t_2} & k_{1t_3} & \cdots & k_{1t_n} \\ k_{2t_1} & k_{2t_2} & k_{2t_3} & \cdots & k_{2t_n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ k_{mt_1} & k_{mt_2} & k_{mt_3} & \cdots & k_{mt_n} \end{pmatrix} \begin{pmatrix} \frac{c_{t_1}}{C} \\ \frac{c_{t_2}}{C} \\ \vdots \\ \frac{c_{t_n}}{C} \end{pmatrix} \quad (3)$$

So the important degree of the station j on the spatial and temporal distribution

$$Z_i = \sum_{x=1}^{n} k_{jt_j} \frac{c_{t_x}}{C} \ \left(1 \le j \le m\right)$$

4. Station Important Calculation Example Application

4.1. Road Network Model

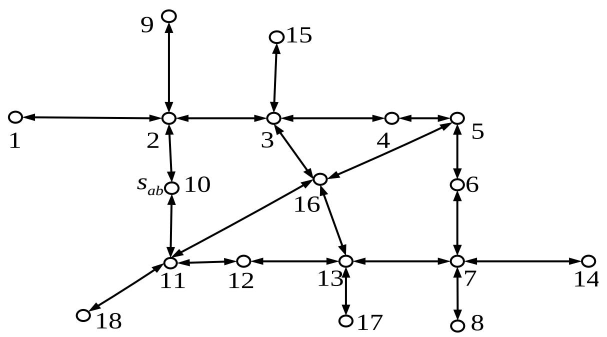

Figure 2. The road network model.

4.2. The Calculation of the Points Strength and the Importance Degree

Assumed that the subway operators time from 6:00 am to 10:00 pm in urban rail network, and the statistical cycle is 16 hours, which is divided into 6:00 - 8:00, 8:00 - 10:00, 10:00 - 12:00, 12:00 - 14:00, 14:00 - 16:00, 16:00 - 18:00, 18:00 - 20:00, 20:00 - 22:00

$$\left(t_1, t_2, t_3, t_4, t_5, t_6, t_7, t_8\right).$$

The following is **Tables 1-3** show the 18 station traffic of the road network in the statistical cycle.

The importance degree of the station can be calculated through the above data into the formula (1), (2) and (3) (see the formula on the bottom of the page).

From **Figure 3**, the degree of importance of the station 2, station 3, station 5, station 7 and station 11, station 13 and station 16 is significantly larger than the other stations, and these stations is the bigger traffic, the larger node degree and the transfer station, which fits the important degree of formula and method of the above calculation station.

5. Conclusion

This paper provided the point definition and calculation of the intensity of the urban rail transit station based on the node degree in passenger traffic and road network model, and gave the concept and the specific calculation method of the station importance degree according to

$$\begin{pmatrix} Z_1 \\ Z_2 \\ Z_3 \\ Z_4 \\ Z_5 \\ Z_6 \\ Z_7 \\ Z_8 \\ Z_9 \\ Z_{10} \\ Z_{11} \\ Z_{12} \\ Z_{13} \\ Z_{14} \\ Z_{15} \\ Z_{16} \\ Z_{17} \\ Z_{18} \end{pmatrix} = \begin{pmatrix} 0.02 & 0.02 & 0.01 & 0.01 & 0.02 & 0.02 & 0.02 & 0.01 \\ 0.49 & 0.42 & 0.28 & 0.35 & 0.37 & 0.46 & 0.49 & 0.39 \\ 0.33 & 0.38 & 0.47 & 0.27 & 0.29 & 0.33 & 0.35 & 0.32 \\ 0.06 & 0.07 & 0.05 & 0.05 & 0.08 & 0.07 & 0.09 & 0.05 \\ 0.19 & 0.18 & 0.17 & 0.18 & 0.19 & 0.21 & 0.23 & 0.13 \\ 0.07 & 0.08 & 0.10 & 0.13 & 0.09 & 0.07 & 0.08 & 0.10 \\ 0.59 & 0.34 & 0.39 & 0.48 & 0.38 & 0.62 & 0.36 & 0.40 \\ 0.02 & 0.03 & 0.02 & 0.02 & 0.03 & 0.02 & 0.03 & 0.02 \\ 0.03 & 0.02 & 0.02 & 0.03 & 0.03 & 0.03 & 0.03 & 0.04 \\ 0.07 & 0.07 & 0.05 & 0.09 & 0.08 & 0.07 & 0.09 & 0.10 \\ 0.46 & 0.45 & 0.46 & 0.38 & 0.43 & 0.41 & 0.43 & 0.24 \\ 0.04 & 0.02 & 0.03 & 0.03 & 0.03 & 0.04 & 0.03 & 0.05 \\ 0.28 & 0.39 & 0.50 & 0.37 & 0.39 & 0.31 & 0.23 & 0.37 \\ 0.02 & 0.02 & 0.02 & 0.02 & 0.02 & 0.02 & 0.03 & 0.03 \\ 0.03 & 0.02 & 0.02 & 0.02 & 0.02 & 0.03 & 0.03 & 0.02 \\ 0.53 & 0.70 & 0.64 & 0.66 & 0.61 & 0.44 & 0.47 & 0.68 \\ 0.02 & 0.03 & 0.03 & 0.03 & 0.04 & 0.03 & 0.05 & 0.04 \\ 0.02 & 0.02 & 0.02 & 0.03 & 0.01 & 0.03 & 0.02 & 0.04 \end{pmatrix} \begin{pmatrix} 0.17 \\ 0.15 \\ 0.09 \\ 0.07 \\ 0.15 \\ 0.18 \\ 0.12 \\ 0.07 \end{pmatrix} = \begin{pmatrix} 0.02 \\ 0.42 \\ 0.34 \\ 0.07 \\ 0.19 \\ 0.08 \\ 0.46 \\ 0.02 \\ 0.03 \\ 0.08 \\ 0.42 \\ 0.03 \\ 0.34 \\ 0.02 \\ 0.02 \\ 0.57 \\ 0.03 \\ 0.02 \end{pmatrix}$$

Table 1. The in and out of the station traffic.

Station	6:00 - 8:00	8:00 - 10:00	10:00 - 12:00	12:00 - 14:00	14:00 - 16:00	16:00 - 18:00	18:00 - 20:00	20:00 - 22:00
1	206	146	56	34	134	226	114	43
2	653	489	234	224	421	623	456	214
3	450	447	357	168	345	453	333	174
4	312	297	138	97	313	342	298	89
5	356	302	198	112	298	396	302	95
6	321	338	256	254	345	334	278	178
7	773	403	302	257	436	873	339	231
8	154	214	104	78	225	164	198	66
9	246	202	89	113	245	266	224	132
10	367	298	135	164	334	361	287	177
11	608	517	347	226	487	588	398	118
12	196	78	67	59	135	213	99	77
13	394	462	325	224	441	402	227	195
14	148	134	123	89	188	168	168	115
15	252	189	97	74	176	257	176	63
16	704	786	467	371	665	604	442	337
17	212	228	175	115	331	262	298	147
18	203	135	88	126	114	253	132	121
Total	6555	5665	3558	2785	5633	6785	4769	2572

Table 2. The transfer traffic.

Station	6:00 - 8:00	8:00 - 10:00	10:00 - 12:00	12:00 - 14:00	14:00 - 16:00	16:00 - 18:00	18:00 - 20:00	20:00 - 22:00
2	553	389	134	114	321	523	356	123
3	350	347	257	89	245	354	243	98
5	256	202	102	113	211	296	200	56
7	673	305	204	208	334	665	256	114
11	508	417	246	145	376	442	304	89
13	294	362	326	134	346	365	145	118
16	604	667	367	268	557	498	334	247
Total	3238	2689	1636	1071	2390	3143	1838	845

Table 3. The degree of the station.

Station	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
The Degree	1	4	4	2	3	2	4	1	1	2	4	2	4	1	1	4	1	1

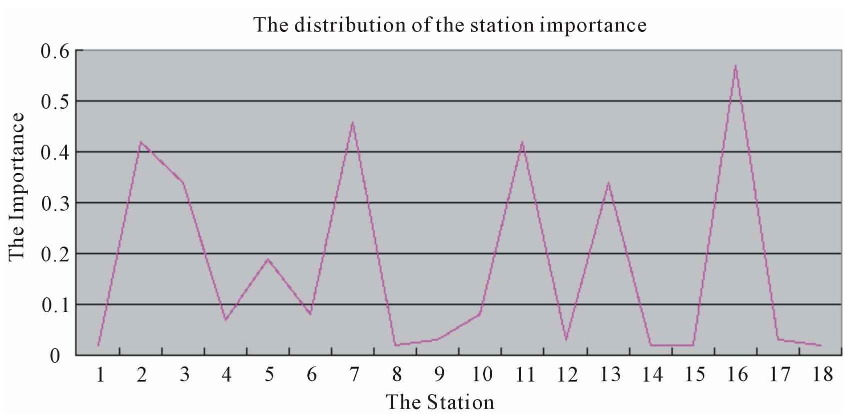

Figure 3. The distribution of the station importance.

the characteristics of the spatial and temporal distribution. It embodied the abstract important degree and specific validation to support the management of the station.

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