APPRAISAL OF URBAN HARMONIOUS TRANSPORT

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Abstract: Beijing has experienced abundant development and a mass of problems in urban transportation. Both transportation facilities and transit capacity have been improving continuously; the rate of public transport mode has also been increased steadily. But, the rate of private car transit increased and the rate of green transport mode, i.e. walking and bicycling declined steadily at the same time. Besides, severe congestion has aroused a lot of criticism. Thus, a comprehensive view of Beijing urban transport is important. In this paper, the authors develop a municipal harmonious transport evaluation system. Then, the authors propose tools in evaluating municipal harmonious transport system. Finally, the paper analyzes Beijing urban transport system harmonious degree empirically and makes a temporal comparison from year of 2001 to 2009.

1 INTRODUCTION

Beijing is in the process of rapid urbanization and motorization. Both transportation facilities and transit capacity, such as number of motor vehicles, length and areas of roads have been improving continuously or even significantly in recent years. According to the data in Beijing statistical yearbook, number of motor vehicles in Beijing has increased from 2.124 million in 2003 to 4.019 million in 2009. Length and areas of the eight districts of Beijing City also climbed to 6247 kilometres and 91.79 million square meters from 3727 kilometres and 73.44 million square meters respectively.

But Downs Law indicates that the increase of transportation supply will boost the traffic demand. The new roads will be occupied quickly by the traffic flow (Downs, 1962).It is also verified by the practice of Beijing. From 2003 to 2009, the number of motor vehicles number, road length in Beijing length and areas in the eight districts of Beijing City increased by 89.3%, 44.8%, 67.6% and 25.0% respectively. It is obvious that the road construction can not meet the traffic demand caused by motor vehicles growth.

Thus, a series of policies and measures have been put forward for transportation demand management. Among the policies, devoting major efforts to develop public transport is the first choice. Public transport priority strategy was brought forward by Beijing government in 2003. At the same time, the status of public transportation as public welfare and service was confirmed. Concessionary fares have been offered to pubic transport users since 2007. Besides, the government has being strived to optimize bus network and speed up the construction of urban railway system. The length of operating urban railway system extended to 199km in 2008, 228 km in 2009 and 336 km in 2010 from that of 114 km in 2003. Public transport in Beijing developed rapidly as a result. The number of passengers by buses and trolleybuses increased from 3.794 billion in 2003 to 5.165 billion in 2009; the number of passengers by urban rail increased from 472 million to 1.423 billion during the same period. Accordingly, the rate of public transport users enlarged from 28.2% in 2003 to38.9% in 2009 (Qiu, 2010).

In spite of the improvement in public transport sector, the green travel mode declined substantially: rate of cycling declined from 38.4% in 2000 to 18.1% in 2009 (Qiu, 2010). Furthermore, travels by private cars boost sharply. Private cars drive 15 thousand kilometer a year on average which is 1.5 times of London and 2 times of Tokyo. In addition, 40% of the trip is less than 5 km in distance, which indicates that commuters are weak consciousness of green commute. The above reasons result in the serious traffic congestion in Beijing.

During the fast urbanization and motorization process, Beijing has taken a series of measures to

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improve the level of transportation management and service. In spite of the great progress made, there are still some crucial problems need to be solved. This paper focuses on whether the urban transport realized harmonious development.

2 MUNICIPAL HARMONIOUS TRANSPORT EVALUATION SYSTEM

The function of urban transport is providing necessary conditions for residents travel. Urban transportation system can be considered as a complex system which is comprised of three subsystems: transportation modes, transportation organization and transportation facilities. Transportation modes include walking, cycling, bus, metro, taxi and private car. Transportation facilities mainly consist of urban road, urban rail and service facilities such as bus stations, parking facilities, transportation hubs and illumination facilities. Transportation organization is the aggregation of soft measures for traffic problems, including transportation management measures and policies.

The coordinated development of the three subsystems is the essential feature of Urban Harmony Transport. What is more, the three subsystems interact with economic development level, environment, resources, technique and policies. As a consequence, in an urban harmonious transport system, the simultaneous improvement of internal subsystems and the external factors is expected to meet the travel demand as much as possible.

According to the above analysis, this paper argues that municipal harmonious transport level should be evaluated by three aspects: transportation service level, scientificity of resources allocation, coordination between transportation and environment. Considering of the availability of the data, five indicators include ‘accidents per 10000 motor vehicles (A_1)’, ‘deaths per 10000 motor vehicles (A_2)’, ‘direct economic losses in traffic accident (A_3)’, ‘rate of lighting lines (A_4)’ and ‘number of intersection monitors (A_5)’ will be used in evaluating urban transport service level. The following indicators are set to evaluate the scientificity of resources allocation: ‘ratio of transport investment (B_1)’, ‘ratio of public transport investment (B_2)’, ‘ratio of suburban transport investment (B_3)’, ‘ratio of suburban public transport investment (B_4)’, ‘road density (B_5)’, ‘area of road per person (B_6)’, ‘ratio of urban roads areas (B_7)’, ‘number of public vehicles per 10000 persons (B_8)’ and ‘ratio of passengers carried by taxis to that of public traffic (B_9)’. In reflecting the coordination between transportation and environment, we adopt ‘ratio of days have 1st or 2nd class air quality(C_1)’, ‘average inhalable particles (C_2)’, ‘average NO_2 concentration (C_3)’ and ‘average noises db along arterial roads (C_4)’.

3 EVALUATION METHOD AND MODEL

Based on the evaluation index system stated above, the tendency of the transport harmony degree of Beijing from the year of 2001 to 2009 is studied in this part of the paper.

3.1 Method in Calculating Indicators’ Weight

Entropy method is adopted here to calculate the weights of evaluation indicators. Entropy is the measurement of the disorder degree of a system and it can measure the amount of useful information with the data provided (Zou, 2006). Calculating the weights of indicators with entropy method is scientific and objective. The steps of calculating can be expressed as follows.

(1) Formation of the evaluation matrix. Suppose there are *m* indicators and *n* evaluation objects, the evaluation matrix X can be defined as

$$X = \begin{pmatrix} x_{11} & x_{12} & \dots & x_{1n} \\ x_{21} & x_{22} & \dots & x_{2n} \\ \dots & \dots & \dots & \dots \\ x_{m1} & x_{m2} & \dots & x_{mn} \end{pmatrix}$$

where x_{ij} is the value of the *j*th evaluation object on the *i*th evaluation indicator.

(2) Standardization of the original evaluation matrix. Because of the difference in the meanings, dimensions and criterions of evaluation indicators, the data need to be pre-processed to transfer into comparable sequence, which is called standardization. The origin evaluation matrix $X = \left(x_{ij}\right)_{m\times n}$ can be translated into $R = \left(r_{ij}\right)_{m\times n}$, where $r_{ij} \in [0,1]$.

If the value of the indicator is the larger the better, then the data should be standardized by the formula as follows:

$$r_{ij} = \frac{x_{ij} - \min x_{ij}}{\max x_{ij} - \min x_{ij}} \quad (1)$$

If the value of the indicator is the smaller the better, then the data should be standardized by the formula as follows:

$$r_{ij} = \frac{\max x_{ij} - x_{ij}}{\max x_{ij} - \min x_{ij}} \quad (2)$$

If the value of the indicator is optimal at a certain value, then the data should be standardized by the formula as follows:

$$r_{ij} = 1 - \frac{\left|x_{ij} - r_i\right|}{\max\left|x_{ij} - r_i\right|} \quad (3)$$

(3) Calculation of entropy and the weight. The entropy of the indicator can be represented as

$$H_i = -K\sum_{j=1}^{n} f_{ij} \ln f_{ij} \quad (4)$$

where $f_{ij} = r_{ij} \Big/ \sum_{j=1}^{n} r_{ij}$, $K = 1/\ln n$.

The weight of the ith indicator can be calculated by

$$w_i = 1 - H_i \Big/ m - \sum_{i=1}^{m} H_i \quad (5)$$

3.2 Evaluation Model

There are many influencing factors of the transport harmony degree. The evaluation index system we use is quite incomplete due to the limit in data. Synthetic evaluation method based on grey relational analysis is adopted in this paper to evaluate the transport harmony degree. The grey system theory was built and extended by Deng (1982, 1989, 1991, 1992 and 1995) and Liu (2004) et.al. Grey relational analysis is a branch of grey system theory. The essence of the method is analyzing and comparing the geometric proximity between the factors curves and the result curve. The more similar, the larger the relational degree is. The synthetic evaluation model based on grey relational analysis can be represented as $P = E \times W$, where P is the vector of the evaluation results (while each element of the vector is a relational degree), W is the weights vector of the indicators which the sum of the elements is 1.

$$E = \begin{pmatrix} \varepsilon_1(1) & \varepsilon_1(2) & \ldots & \varepsilon_1(m) \\ \varepsilon_2(1) & \varepsilon_2(2) & \ldots & \varepsilon_2(m) \\ \ldots & \ldots & \ldots & \ldots \\ \varepsilon_n(1) & \varepsilon_n(2) & \ldots & \varepsilon_n(m) \end{pmatrix}$$

Where $\varepsilon_j(i)$ is the grey relational coefficient between the jth object on the ith indicator and the optimum value of the ith indicator. When finishing the calculation of the grey relational degree, the sorting of objects could be presented based on the value of P.

The calculation steps are presented as follows:

(1) The sequence of each indicator should be presented as

$$X_1 = (x_{11}, x_{12}, \ldots, x_{1n})$$
$$X_2 = (x_{21}, x_{22}, \ldots, x_{2n})$$
$$\ldots\ldots\ldots\ldots\ldots\ldots$$
$$X_m = (x_{m1}, x_{m2}, \ldots, x_{mn})$$

where x_{ij} is the value of jth evaluation object on the ith indicator, m is the number of indicators and n is the number of evaluation objects.

(2) The optimum sequence of the indicators. Suppose that $X^* = (x_1^*, x_2^*, \ldots, x_n^*)$ is the optimum sequence of the indicators, where x_i^* the optimum value of evaluation objects on the ith indicator. The principle of the optimum value is that if the value of a indicator is the larger the better, then the maximal value is optimum; if a indicator is the smaller the better, then the minimal value is optimum; if a indicator is optimum at a certain value, then the value is optimum.

With the optimum sequence confirmed, matrix D can be constructed as

$$D = \begin{pmatrix} x_{11} & \ldots & x_{1n} & x_1^* \\ x_{21} & \ldots & x_{2n} & x_2^* \\ \ldots & \ldots & \ldots & \ldots \\ x_{m1} & \ldots & x_{mn} & x_m^* \end{pmatrix}$$

(3) Standardization of the data sequence. Because of the difference in the range and dimension of evaluation indicators, the data need to be pre-processed to transfer into comparable sequence. Formula (1), (2), (3) is generally used for standardization. The standardized matrix can be represented as

$$R=\begin{pmatrix} r_{11} & \dots & r_{1n} & r_1^* \\ r_{21} & \dots & r_{2n} & r_2^* \\ \dots & \dots & \dots & \dots \\ r_{m1} & \dots & r_{mn} & r_m^* \end{pmatrix}$$

(4) Calculation of grey relational coefficient-. Grey relational coefficient $\varepsilon_j(i)$ is the differentials between the indicator sequences and comparison sequence on the ith indicator. The larger the grey relational coefficient is, the bigger the differential is.

Grey relational coefficient can be calculated by the formula as follows

$$\varepsilon_j(i)=\frac{\min\limits_j \min\limits_i \left|r_i^*-r_{ij}\right|+\rho \max\limits_j \max\limits_i \left|r_i^*-r_{ij}\right|}{\left|r_i^*-r_{ij}\right|+\rho \max\limits_j \max\limits_i \left|r_i^*-r_{ij}\right|} \tag{6}$$

where ρ is the distinguishing coefficient, $\rho \in [0,1]$,the distinguishing coefficient is introduced to reduce the influence of the extremum value during the procedure of calculating. The smaller the distinguishing coefficient is, the bigger the distinguishability is. 0.5 is generally used in practical application.

(5) Calculation of grey relational degree. The distinguishing coefficient is used to analyze the relationship between the indicator sequence and the comparison sequence on each indicator. It only reflects one-side information. In order to obtain the relationship between the sequences, grey relational degree is needed. The grey relational degree can be represented as

$$p_j=\sum_{i=1}^{m} w_i \varepsilon_j(i) \tag{7}$$

where w_i is the weight of the ith evaluation indicator.

(6) Sorting. If the grey relational degree p_j is maximal, then R_j is most proximate with the optimum value R^*, which means the *j*th evaluation object is better than others. The evaluation objects could be sorted according to this principle.

4 DYNAMIC ANALYSIS OF THE TRANSPORT HARMONY DEGREE OF BEIJNG

4.1 Calculation of the Indicator Weights

There are 18 evaluation indicators (A1-C4) and 9 objects (from 2001 to 2009) in this case. Values of the indicators which collected from Beijing Statistical Yearbook and Beijing Transport Statiscal Yearbook are presented in Table1.

Entropy can be calculated based on the standardized data. Then weights of indicators are obtained by entropy method.

Table 1: Indicators' data of Beijing harmonious transport system (2001-2009).

Indicators	2001	2002	2003	2004	2005	2006	2007	2008	2009
A_1	132.66	71.34	53.24	37.46	23.88	18.91	14.72	9.30	7.98
A_2	8.8	7.9	7.7	7.6	6.0	4.8	3.8	2.8	2.4
A_3	62670.7	4112.0	4361.1	4058.0	2609.49	2772.0	2285.1	2038.9	2043.4
A_4	31.31	33.71	34.38	41.25	44.25	30.19	28.6	26.2	30.3
A_5	135	212	390	390	440	439	449	537	752
B_1	27.87	37.14	27.15	21.57	25.86	39.21	38.93	39.83	46.27
B_2	45.35	29.16	43.03	52.96	71.68	54.79	44.22	46.69	63.09
B_3	1.52	0.89	8.17	0.00	0.82	0.00	0.03	0.19	0.26
B_4	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.55
B_5	2.68	2.67	2.72	2.97	2.98	3.23	3.26	4.52	4.56
B_6	5.85	5.71	7.94	7.73	7.81	6.18	6.20	8.56	8.50
B_7	3.7114	3.9026	5.361	5.3255	5.4395	5.1793	5.5776	6.5343	6.7082
B_8	13.74	12.35	13.29	14.54	13.55	12.96	12.57	13.7	13.5
B_9	13.31	12.16	12.13	11.43	12.37	13.69	13.13	11.65	10.32
C_1	50.68	55.62	61.37	62.7	64.1	66	67.4	75.1	78.1
C_2	0.165	0.166	0.141	0.149	0.142	0.161	0.148	0.122	0.121
C_3	0.071	0.076	0.072	0.071	0.066	0.066	0.066	0.049	0.053
C_4	69.6	69.5	69.7	69.6	69.5	69.7	69.9	69.6	69.7

Source: Beijing Statistical Yearbook (2001-2009), Beijing Transportation Yearbook(2001-2009).

w_i=（0.018，0.042，0.015，0.041，0.029，0.034，0.025，0.148，0.276，0.081，0.047，0.032，0.032，0.036，0.028，0.049，0.043，0.020）

4.2 Synthetic Evaluation of Beijing Transport Harmonious Level

According to the data in Table 1 and indicators' weight, optimum sequence is constructed as

$$X* = (7.98, 2.4, 2038.9, 44.25, 752, 46.27, 71.68, 8.17, 6.55, 4.56, 8.56, 6.7082, 14.54, 10.32, 78.1, 0.121, 0.049, 69.5)$$

Calculation with the standardized data, the grey relational degrees of 2001-2009 is 0.368，0.386，0.513，0.450，0.479，0.417，0.424，0.598，0.832 respectively.

Thus, we conclude that the order of the transport harmony degree of Beijing from 2001 to 2009 is 2009>2008>2003>2005>2004>2007>2006>2002 >2001

5 CONCLUSIONS

In this paper, we evaluate Beijing urban transport harmonious level dynamically. The research indicates that Beijing urban transport harmonious level improved obviously in 2009 and 2008. The main reasons for the improvement lie in enlarged ratio of investment in transport (including public transport), improvement in transport infrastructure and decrease in occurrence and loss of traffic accidents. Efforts by the municipal government play important role in these. Development of public transportation, e.g. rail, bus and trolley bus contributes a lot to transport harmony. But for a metropolitan city, attention and cooperation from the public will be more effective.

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