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Traffic Performance Quality Level Classification and Evaluation of Road Network Planning Based on Improved TOPSIS Method

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Abstract: The future traffic state is one of importance considered factors in decision of road network planning. To judge the traffic quality that reflected from multiple aspects, a method of Technique Order Preference by Similarity to Ideal Solution (TOPSIS) is adopted in this study to evaluate the traffic performance situation and service level of road network planning schemes. On the basis of establishing the levels of traffic quality indexes, the algorithm of calculating the comprehensive relative closeness degree to the level interval is proposed. The scheme evaluation and selection process is illustrated by an example analysis which demonstrates that the method is efficient and feasible and has practical value. The method can determine the order of schemes and which level subjected to as well, so can be as one of the basic evaluation model of decision support system of traffic planning.

Key words: Traffic planning, performance quality, scheme evaluation, improved TOPSIS, decision support

INTRODUCTION

In traffic network planning decision support system, in order to analyze and compare different planning schemes whether meet the demand of traffic, it is very important to evaluate and judge the traffic performance situation. The traffic quality evaluation of road network planning schemes is a complicated system involved with a lot of factors and goals. Single evaluation index can only represent a certain performance of the system from one aspect, but not reflect the structure characteristics and benefits of the whole system. So, this evaluation should be an issue of multi-objectives evaluation and decision.

There are several comprehensive evaluation approaches, such as analytic hierarchy process (Xu and Wu, 2006), fuzzy comprehensive evaluation (Xiong and Yan, 2003) and matter element analysis method (Zheng *et al*., 2004). In addition, the method of Technique Order Preference by Similarity to Ideal Solution (TOPSIS) has been widely applied to problems of evaluation and decision in many fields and obtained favorable effect. The application fields include the cost forecasting (Li, 2013), the freight transportation mode selection (Gai and Li, 2009), the bid evaluation of construction (Xu *et al*., 2012), the evaluation of river regulation schemes (Xu *et al*., 2013), the supplier evaluation (Tian *et al*., 2013) and so on. Olson (2004) compared different weights and different distance metrics in TOPSIS. There are some researches focused on the application and extension for group decision-making (Jiang, 2013; Shih *et al*., 2007). This study aims to study the judgment of the classification of traffic quality level with application of TOPSIS method for the sake of comparison and selection of road network planning schemes.

PROCESS OF SCHEME DETERMINATION OF ROAD NETWORK PLANNING

Planning of traffic system should meet the demand of society and economy. Accurately forecasting of traffic demand is the basis of planning. The planning of traffic network is the process of continuously satisfying with the traffic demand. Through the steps of trip production, trip distribution, modal split and traffic assignment, the network planning schemes can be proposed. The trip production is to determine the trip generation and trip attraction of traffic zones which are related with land-use, population, ownership of vehicles, layout of manufacturing, characteristics of city and so on; trip distribution is to determine the tabulation of trip origin and destination between traffic zones; modal split is to estimate the mode choice of trip according to traffic service level and utility, such as time, cost, comfort, convenience and safety; traffic assignment is to assign forecasted traffic to road with routing shortest time paths and determine the load of road network (Bell and Iida, 1997; Lu, 1998).

Alternative plans can be evaluated by the estimation of costs and benefits and the decision can be made according to the ranking of planning schemes. Through evaluation can analyze the probability of planning achieving anticipated goals and provide decision basis for selecting optimal planning schemes. The process of traffic network planning and decision-making is shown in Fig. 1.

EVALUATION INDEX SYSTEM

Determination of indexes for traffic quality: The performance of a traffic network system is measured against a series of goals and objectives. So to evaluate and choose the excellent scheme from alternative planning schemes should establish identical criterion that is, evaluation index system to compare and measure all the alternatives. Therefore, the evaluation should strive to reflect the synthetic circumstances of alternatives overall. It is required that the evaluation can reflect the internal structure and function of the system and can assess the relationship between the system and the external environment correctly as well; it can reflect the direct effect and the indirect effect as well which can assure the completeness and reliability of the evaluation.

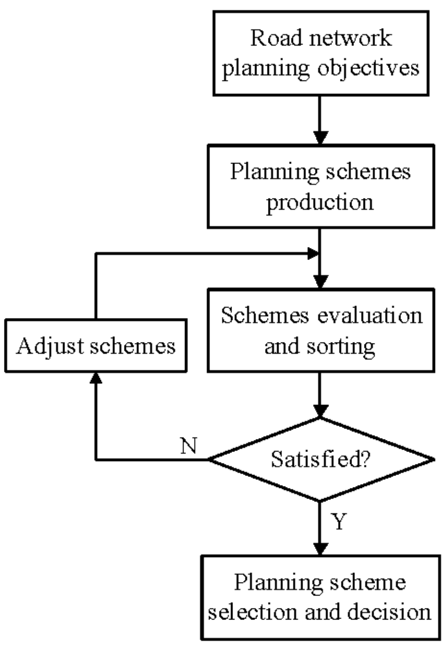

Fig. 1: Process of road network planning

The traffic quality of road network on the one hand is to see from the point of view as a whole how the utilized efficiency is and whether the roadway of all levels can give rational and full play; on the other hand from the road users' point of view whether the road is unobstructed and how the condition of the traffic flow in road sections and intersections is (Jun *et al*., 2002). The optimum scheme can obtain better traffic quality with less delay in road sections and intersections, lower congestion rate and faster travel speed. The evaluation index system should scientifically, objectively and as all-sidedly as possible consider all factors. It is suggested to select relatively independent, common and quantitative indexes and use as fewer indexes as possible under the condition of meeting evaluation request. Considering evaluation being in planning stage, according to systematic, scientific, comparable and practical criterions and easily to acquire data, an comprehensive evaluation index system is established, shown in Table 1 and every index acts on all planning schemes.

c_1 and c_2 reflects the traffic load and congestion degree of road network. The higher its value the greater utilization intensity of road network is. The ideal value is 0.8 for saturation. c_3 reflects the uniformity of traffic volume distribution in network. c_4 reflects the quantity of road sections whose level of service is low. The higher value shows the congested roads in network are more, the road traffic flow is not fluent and the level of service is low. c_5 reflects the average running condition for the motor vehicles in road network. The arterial road is the framework of urban road network which serve as traffic character function, taking on mostly passengers and goods transportation in the city, so it is required offer faster travel speed. c_6 is an index to judge whether the arterial road give well play to the traffic character function which reflects the free level on the arterial road. Every road differs in traffic volume and length, so weighted average traffic volume and length of road sections are adopted. The data of traffic performance situation can be obtained through traffic assignment and traffic flow simulation if bringing the planning schemes of road network into effect.

On account of the different degree of every factor's impact on traffic running quality, it is needed to give

Table 1: Evaluation index system for traffic quality of road network planning scheme

Code	Index	Illustration
c_1	Average saturation of road section	It is the average rate of traffic volume on the road section to road capacity.
c_2	Average saturation of main road	It is the average rate of traffic on secondary trunk road and above to road network capacity.
c_3	Load nniformity	It indicates the traffic load difference of all road section.
c_4	Kilometrage congestion rate	It is the proportion of length of road whose saturation is greater than 0.8 to overall road lengths.
c_5	Average travel speed of road sections (km.h^{-1})	It is the average travel speed of motor vehicles in all sections of roads.
c_6	Average travel speed of arterial road (km.h^{-1})	It is the average travel speed of motor vehicles on arterial road and expressway.

corresponding weight to every index according to the different function in traffic quality. The weight can be given by experience and also usually determined by method of expert estimation, weighted statistics, frequency statistics and analytic hierarchy process.

Classification of evaluation level of traffic quality: Referring the grading standard of road service level and combined with experts' suggestions, the traffic quality of planning schemes are classified into 5 levels, A, B, C, D and E, A is the best and D is the worst. In order to unify the comparing criterion, firstly standardize the indexes attribute values to interval [0,1].

To index c_1 and c_2, as they are fixed index, the converting equation is:

$$r_{ij} = 1 - \frac{|a_{ij} - 0.8|}{0.8} \quad (1)$$

where, a_{ij} is the index value of the ith scheme and the jth index, i = 1,..., m, j = 1, 2.

To index c_3 and c_4, the value itself is belong to [0,1], so they need not be converted. But they are cost index, it need convert them to benefit index that is:

$$r_{ij} = 1 - a_{ij} \quad (j = 3, 4) \quad (2)$$

While to index c_5, the grades intervals are defined as follows: A = [48, 80], B = [40, 48], C = [32, 40], D = [24, 32], E = [0, 24].

To index c_6, the grades are defined: A = [60, 80], B = [50, 60], C = [40, 50], D = [30, 40], E = [0, 30]. Then the standardizing equation is:

$$r_{ij} = \frac{a_{ij}}{\max a_{ij}} \quad (j = 5, 6) \quad (3)$$

So, the value ranges of each level to every index can be obtained, shown in Table 2.

IMPROVED TOPSIS MODEL FOR TRAFFIC QUALITY EVALUATION

If every attributes value of the planning scheme cannot satisfy all the conditions of classification, it is difficult to judge which level it belongs to. TOPSIS is a multiple attributes decision method to identify solutions with ranking and selection from a number of determined alternatives through judge distance to ideal solution and negative ideal solution (Shih *et al*., 2007; Xu and Chen, 2009). It is an effective method to solve multiple objectives decision problems. It needs define a distance measures to estimate the degree of closeness to the best point and the farness to worst point. The usual measure is Euclidean distance from the attributes values of scheme to ideal point. Aiming at the characteristics of traffic quality evaluation, it need not only ranking schemes but also determining which level the schemes subjected to, so it is necessary to assess the distance to every grade intervals.

If there are m schemes with n attributes, suppose $[a_j^k, b_j^k]$ denotes the interval of the kth level for the jth index. Use the relative closeness degree to measure the relationship between attribute value and level interval. Let b_j^k is the ideal solution and a_j^k is the negative ideal solution. Define the distance to ideal solution $s_j^{k+} = b_j^k$ is:

$$D_{ij}^{k+} = r_{ij} - b_j^k \quad (4)$$

The distance to negative ideal solution $s_j^{k-} = a_j^k$ is:

$$D_{ij}^{k-} = r_{ij} - a_j^k \quad (5)$$

Then the relative closeness degree of the scheme i for evaluated with respect to the level j is defined as:

$$C_i^k = \sum_{j=1}^{n} w_j \frac{D_{ij}^{k-}}{D_{ij}^{k-} - D_{ij}^{k+}} = \sum_{j=1}^{n} w_j \frac{D_{ij}^{k-}}{b_{ij}^k - a_{ij}^k} \quad (6)$$

where, w_j is the weight of attribute.

The magnitude of the relative closeness degree shows the degree of the scheme measuring up to the traffic quality level. The evaluation rules are:

- If $C_i^k > 1$, it denotes that the scheme is superior to the level k
- If $0 < C_i^k = 1$, it denotes that the scheme is subjected to the level k
- If $C_i^k = 0$, it means that the scheme is inferior to the level k

Table 2: Level classification of evaluation indexes for traffic quality of road network planning scheme

Evaluation index	A	B	C	D	E
c_1	[0.9, 1]	[0.8, 0.9]	[0.7, 0.8]	[0.6, 0.7]	[0.5, 0.6]
c_2	[0.9, 1]	[0.8, 0.9]	[0.7, 0.8]	[0.6, 0.7]	[0.5, 0.6]
c_3	[0.8, 1]	[0.6, 0.8]	[0.4, 0.6]	[0.2, 0.4]	[0, 0.2]
c_4	[0.8, 1]	[0.6, 0.8]	[0.4, 0.6]	[0.2, 0.4]	[0, 0.2]
c_5	[0.6, 1]	[0.5, 0.6]	[0.4, 0.5]	[0.3, 0.4]	[0, 0.3]
c_6	[0.75, 1]	[0.625, 0.75]	[0.5, 0.625]	[0.375, 0.5]	[0, 0.375]

Then it can sort the alternatives from high to low on the ground of subjected level. When there is more than one scheme subjected to the same level, the greater the closeness value the traffic quality is better. Thus it can provide quantitative basis for decision-making of the network planning schemes.

EXAMPLE

If there are five road network planning schemes to be evaluated and selected, according to Eq. 1-3, standardize the original data of scheme indexes value of traffic quality and the obtained result is shown in Table 3.

Apply AHP method to determine the weight of every index. According to the opinion of experts through pairwise comparing the index importance, construct the reciprocal judgment matrix as follows:

$$A = \begin{pmatrix} 1 & 1/3 & 3 & 4 & 4 & 3 \\ 3 & 1 & 4 & 5 & 5 & 4 \\ 1/3 & 1/4 & 1 & 3 & 3 & 2 \\ 1/4 & 1/5 & 1/3 & 1 & 4 & 3 \\ 1/4 & 1/5 & 1/3 & 1/4 & 1 & 1/3 \\ 1/3 & 1/4 & 1/2 & 1/3 & 3 & 1 \end{pmatrix}$$

With the eigenvalue method, calculate and obtain the weight vector w = (0.2395, 0.4065 0.1360 0.1026, 0.0422, 0.0732). $\lambda_{max} = 6.605$, CI = 0.121, RI = 1.24, CR = 0.0976<0.1, so it can pass the consistence examination.

According to Eq. 4-6, the relative closeness degree to all the grade of traffic performance quality level of these alternative schemes can be obtained which is shown in Table 4.

It can be seen from the result, to scheme a_1, $0<C_1^B = 0.8603<1$, therefore, $a_1 \in \{B\}$, i.e., the traffic quality of scheme a_1 belongs to the level B. Similarly, we can obtain, respectively scheme a_2 belonging to level A, scheme a_3 belonging to level A, scheme a_4 belonging to level B, scheme a_5 belonging to level C. Although a_2 and a_3 both belong to level A, the relative closeness degree to level A of a_3 is more than a_2, so a_3 is superior to a_2 and the same as a_1 and a_4. Consequently, the ranking of the alternatives is:

$$a_3 \succ a_2 \succ a_1 \succ a_4 \succ a_5$$

So, we select the optimal scheme a_3 from these alternatives as recommended planning scheme.

Table 3: Standardized index attribute value of planning schemes

Scheme	c_1	c_2	c_3	c_4	c_5	c_6
a_1	0.9000	0.9375	0.75	0.47	0.5625	0.6250
a_2	0.9375	0.8750	0.70	0.35	0.4375	0.6250
a_3	0.9375	0.9375	0.82	0.68	0.4750	0.6875
a_4	0.9250	0.9750	0.58	0.42	0.3750	0.5250
a_5	0.7500	0.8125	0.50	0.57	0.6000	0.6875

Table 4: Calculation result of the relative closeness degree

Scheme	A	B	C	D	E
a_1	-0.0914	0.8603	1.8604	2.8605	3.6891
a_2	0.6086	1.0583	1.5310	2.9503	3.7789
a_3	0.7286	1.0958	1.5460	2.9503	3.7789
a_4	-0.0693	0.7937	1.7938	2.7939	3.7143
a_5	-1.0553	-0.0735	0.9266	1.9267	2.7204

CONCLUSION

Traffic system plan is a problem of multiple objectives and it is influenced by exceedingly extensive range. In accordance with this characteristic, to evaluate the scheme should use comprehensive evaluation method. This study based on the thought of TOPSIS, in order to classifying the level grade of traffic performance quality defined the distance measure to grade interval. With the relative closeness degree index, the ranking and difference between schemes can be determined. Through constructing the traffic quality assess model of multiple index parameters, expressing evaluating results by quantitative data and transforming the multiple objectives to single objective to be analyzed which provides another way for evaluation and classification of road network planning. The given example shows this improved method is simple and effective and has practical application. The method can not only sort the planning schemes, but also determine the level of traffic quality. It can reflect the comprehensive level of traffic quality completely, so as to provide decision support for selection and decision of optimum road network planning scheme.

REFERENCES

Bell, M.G.H. and Y. Iida, 1997. Transportation Network Analysis. John Wiley and Sons, USA., ISBN: 9780471964933, Pages: 216.

Gai, Y.X. and C. Li, 2009. Application of hybrid TOPSIS method to evaluation of freight manner in integrated transportation system. J. Lanzhou Jiaotong Univ., 28: 91-94.

Jiang, Q., 2013. Application of TOPSIS for group decision. Jiangxi Sci., 31: 549-551.

Jun, L., L.X. Hong and X.Z. Cai, 2002. Research for index system of traffic quality valuation in municipal traffic network planning. Sci. Tech. Inform. Water Transp., 3: 47-49.

Li, J., 2013. Cost combination forecasting approach and application based on TOPSIS. Stat. Decision, 4: 71-73.

Lu, H.P., 1998. Traffic Planning Theory and Method. Tsinghua University Press, Beijing.

Olson, D.L., 2004. Comparison of weights in TOPSIS models. Math. Comput. Modeling, 40: 721-727.

Shih, H.S., H.J. Shyur and E.S. Lee, 2007. An extension of TOPSIS for group decision making. Mathem. Comput. Modell., 45: 801-813.

Tian, R., L. Sun, B. Li and W. Liao, 2013. Supplier evaluation by TOPSIS based on fuzzy rough set. Appl. Res. Comput., 30: 2319-2322.

Xiong, Q. and Q. Yan, 2003. Multi-layer fuzzy comprehensive assessment of urban highway passenger stations layout planning. J. Huazhong Sci. Technol. (Urban Sci. Edn.), 20: 60-63.

Xu, C., D, Zhai, S. Zhang and D. Hu, 2013. Application of improved TOPSIS comprehensive evaluation model to optimization of river regulation schemes. J. Hohai Univ. (Nat. Sci.), 41: 222-228.

Xu, J. and J. Chen, 2009. The Theory and Methods of Group Decision Making with its Realization. Tsinghua University Press, Beijing.

Xu, J. and W. Wu, 2006. Multiple Attributes Decision Making Theory and Methods. Tsinghua University Press, Beijing, China.

Xu, Y., S. Tao and L. Zeng, 2012. Entropy weight and TOPSIS based bid evaluation model of construction applied research. J. Eng. Manage., 26: 62-65.

Zheng, C., S. Chen and W. Wang, 2004. A matter-element based approach to evaluating alternatives of priority of public transit at intersections. J. Highway Transp. Res. Dev., 21: 98-101.