FUZZY OPTIMIZED CHOICE FOR HIGHWAY NETWORK PLANNING ALTERNATIVES

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Abstract: This paper describes the evaluating index system for highway network evaluation. It also applies the fuzzy conformity degree theory to the alternative choice and obtains some satisfactory results.

Key words: Highway network, Evaluation index, Alternative choice

1. PREFACE

Highway network planning is a multi-level, multi-objective and multi-factor complex system. According to development strategy, transportation demand, investment scale, construction capacity and other constraint conditions, there might be multiple alternatives drafted for selection. Owning to the difference and overlap among indices respectively adopted for each alternative, it is very important and necessary to develop approaches to evaluating alternatives and subsequently select the preferred one. This methodology, as termed Optimized choice for Highway Network Planning, is discussed in this paper.

2. SELECTION OF THE EVALUATING INDICES

Evaluating indices, as physical values to describe and reflect properties of alternatives, are basic criterions for alternative comparison and choice. The indices ultimately selected should be scientific, rational and concise so that they can not only comprehensively reflect the properties of alternatives but also be easily obtained and quantified. Besides, they are also required to be independent of each other. Generally, highway network evaluation is measured in four aspects: adaptability, feasibility, economic performance and rationality. The first three indices are quantitative indices that can be reached by detailed computation, while the last one is a qualitative index, which can be normally obtained by expert assessment. Considering the characteristics of highway network planning, the last index should be the first to be evaluated in the choice of alternatives. The detailed indices are shown in table.1.

Table.1 Indices for Highway Network Evaluation

	Adaptability	Rationality	Feasibility	Economic performance
Indices	Connectivity level Network grade Pavement rate Crowding level Crowding mileage Network speed	Economic effect Political effect Cultural effect	Investment Land use	Transportation cost Cost-benefit ratio Internal rate of return

Among these indices, connectivity level is the ratio of the number of sides of the network structure to the number of nodes, which reflects the accessibility between nodes and the frame structure of the network. Pavement rate and network grade directly embody the technical level and road conditions. Crowding level macroscopically reflects the network's traffic capacity and its adaptability to the traffic demand; Crowding mileage rate indicates the adaptability to the distribution of road technical grades and traffic volume; Network speed reflects the service level. The rationality of a network project is normally evaluated in three aspects. Politically it strengthens national defense, promote the unity of nationality and maintain national stability. Economically it is consistent with the national policies and programs for socioeconomic development, promotes the exploiting of national resources, betters investment environment, enlarges markets, and improves the local economic development. Socially it enhances inter-zone exchange and connection, increases job opportunities and raises incomes. Feasibility indices reflect the construction cost. As for economic indices, they are difficult to be obtained and have relatively lower confidence level. Therefore they are usually omitted in practice.

These indices reveal the merits and drawbacks of compared alternatives from different angles. As project evaluation is a subjective decision-making process, personal preference should be taken into consideration. Therefore, we assign various weighting factors to the corresponding indices. The weighting factors vary in varying circumstances and they can be normally reached by the means of analytic hierarchy process.

3. THE FUZZY OPTIMIZED CHOICE THEORY

Assume there are m alternatives for selection: A_1, A2,...A_m and n evaluating indices. The index set for the ith alternative is defined as $X_i=(x_{i1},x_{i2},\ldots x_{in})$, i=1,2,... m. If we define A_0 as the reference alternative for comparison, then we get the reference index set $X_0=(x_{01},_{02},\ldots x_{0n})$. Define the membership function of the fuzzy set A:

$$A(x_j) = \begin{cases} x_j / x_{0j}, & x_j \le x_{0j} \\ 2 - x_j / x_{0j}, & x_{0j} < x_j \le 2x_{0j} \\ 0, & x_j > 2x_{0j} \end{cases} \quad (1)$$

Thus we obtained the fuzzy vector $A_0=(a_{01},a_{02},\ldots a_{0n})$ and $A_i=(a_{i1},a_{i2},\ldots a_{in})$, i=1, 2, ... m. Here $a_{0j}=A(x_{0j}) \equiv 1$, $a_{ij}=A(x_{ij})$, j=1,2,...n. Define $Ne(i)=Ne(A_0,A_i)=1-\Sigma\omega_j|a_{0j}-a_{ij}|$, and we call Ne(i) the conformity degree between A_0 and Aj. ω_j is the weighting factor for the jth index, and the sum of ω_j is equal to one. Notice that $a_{0j}\equiv 1$, we rewrite the formula as:

$$Ne(i) = 1 - \sum_{j=1}^{n} w_j |a_{ij} - 1| \quad (2)$$

The conformity degree Ne(i) reflects the extent to which alternative A_i approximates to the reference alternative A_0. When the index set of A_0 is rationally selected, all alternatives may be ranked in terms of their conformity degree values against A_0. It should be said here that the purpose of highway network optimization is to pick up the most relatively preferable one among the all alternatives provided. Therefore, we adopt the optimal values among all index values as reference indices for reference A_0. That is, some maximum values are adopted to indicate some indices such as connectivity, pavement rate and network speed, while some minimum values are adopted to indicate other indices such as network grade, crowding level and aggregate investment. The reference index set of A_0 is denoted by $X_{0j}=\{x_{1j}, x_{2j},\ldots x_{mj}\}$, j=1,2,...n. Obviously, the greater the value of Ne(i) is, the more preferable the alternative will be.

4. APPLICATION

In literature 2, three alternatives were drafted after analyzing the forecast results and considering the historical, political and other relative elements. Now we adopt seven indices to evaluate the alternatives. According to the results of expert consultation and analysis, we got the indices for the alternatives and their respective weighting factors. They were listed in table.2 with the reference indices obtained by the method mentioned above. On the basis of the reference indices, we computed out the three fuzzy vectors shown in table.3 by using the membership function. Finally, we obtained the Ne(i) for each alternative using the formula $N(i)=1-\Sigma\omega_j|a_{ij}-1|$. The values were also listed in table.3. We see the rank of all alternatives in terms of their conformity degrees:

$$Ne(A_3) = 0.920 > Ne(A_1) = 0.725 > Ne(A_2) = 0.546$$

If the symbol >represents "preferred to", it can be concluded that A_3 is preferred to all others, which is consistent with the finale judgement in literature 2. The fact that four reference indices come from A_3 explains the final result .It should be said that weighting factors, as subjective elements adopted by decision makers after considering all possible influlencial factors, may have certain effect on the final result.

Table.2 Indices of Alternatives

Indices	Weight	A_1	A_2	A_3	A_4
Crowding level x_1	0.031	0.9	75	0.12	75
Load uniformity x_2	0.93	0.3	0.5	0.15	15
Economic effect x_3	0.220	9	6	7	9
Layout rational factor x_4	0.220	8.5	7	8.0	8.5
Investment x_5	0.078	70	95	42	42
Technical attainability x_6	0.234	7.5	6	7.5	7.5
Land use x_7	0.124	210	260	93	93

Table .3 Fuzzy Vector a_{ij} of All Alternatives

A_i	a_{i1}	a_{i2}	a_{i3}	a_{i4}	a_{i5}	a_{i6}	a_{i7}	Ne(i)
A_1	0.8	0	1.0	1.0	0.33	1.0	0	0.725
A_2	1.0	0	0.67	0.82	0	0.8	0	1.546
A_3	0.4	1.0	0.78	0.94	1.0	1.0	1.0	0.920

5. CONCLUSION

This paper discusses the evaluating indices and the characteristics of decision-making of highway network planning project and applies the fuzzy conformity degree theory to the choice of alternatives. Being clear thinking and simple, this method can avoid or reduce the effect of abnormal data and has a high-resolution capability. It has been proved workable and practicable. But it should be said that there is still great room for discussion in index selecting and weighting factor determining.

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