MATEC Web of Conferences **124**, 03004 (2017) DOI:10.1051/matecconf/201712403004
ICTTE 2017

Study on Comprehensive Decision of Urban Rail Transit Network Planning

Liu Sheng[1]
[1]*Lanzhou jiao tong University, Lanzhou, China*

Abstract. Based on the research and analysis of urban rail transit network planning, Determining Evaluation Index System of Urban Mass Transit Network.On this basis, the evaluation index system of network planning is established. this paper analyzes and compares the planning scheme of urban rail transit network in a city, and combines the analytic hierarchy process and the gray correlation method so that the alternatives can be discharged in good or bad order.The ranking results can objectively reflect the actual situation of urban rail transit network planning, in order to solve the problem of optimal selection of urban rail transit network planning, a set of objective scheme is proposed to avoid the decision deviation caused by the defects of single decision method.

1 Introduction

Urban rail transit network plan decision is the key step in the urban rail transit network planning, which is the basis of project optimization. The planning of urban rail transit network planning is mainly based on qualitative analysis [1], [2].This paper is based on the analysis of urban rail transit network planning, using analytic hierarchy process (AHP) combined with the GRAY correlation method, and to establish a scientific and rational evaluation index system, the comprehensive analysis of each scheme for qualitative and quantitative solution should selected from the different options for the best program.

Urban rail transit network evaluation is

different from the general urban road network and regional highway network evaluation.To evaluate the urban rail transit network, we must consider various characteristic factors and establish a complete, scientific and comprehensive evaluation system with the actual situation of the urban rail network. In addition, the scale of the rational control index system is also an important aspect [3].According to the above principle,using AHP basic principle, to establish a set of evaluation index system[4], [5] In the specific planning, according to the need for the following table to the appropriate increase or decrease.

2 The urban rail transit network based on Ahp - Gray comprehensive decision method

The factors that affect the urban rail transit network are expressed as hierarchical structure, and the indicators have qualitative and quantitative indicators.In the following,we combine the AHP method and the GRAY method to establish the decision model of urban rail transit network.

2.1 Index weight assignment method-AHP

Analytic hierarchy process (AHP) was proposed in the 1970s by the United States operations researcher T.L.satty for the first time. The method is a combination of quantitative and qualitative methods.it is often used in combination with other evaluation methods to determine the weight of evaluation index [6,7].

AHP method of the basic steps:(1)Create a hierarchical hierarchy model;(2) To construct judgment matrix;(3) Determine the hierarchical weight value;(4) Consistency test of the judgment matrix;

The matrix deviates from the consistency indicator C.I., as in equation (1).

$$\mathrm{C.I.} = \frac{\lambda_{\max} - n}{n - 1} \quad (1)$$

Random Consistency Ratio C.R., as in equation (2).

$$\mathrm{C.R.} = \frac{\mathrm{C.I.}}{\mathrm{R.I.}} < 0.1 \quad (2)$$

(5) Calculate the weight of the elements of each layer.

2.2 The optimal decision-making program-GRAY

Gray correlation method(GRAY) is a multi-factor integrated decision-making method.It can make full use of the existing information to reduce the error by using the Gray correlation degree as the measure, and provide a simple and applicable method for the optimization decision making[8], [9] In the above analysis, this paper establishes the optimization model of urban rail transit network planning and evaluation decision-making system, and puts forward a decision method based on Gray relational decision-making method.

2.2.1 Determine the decision matrix

Assume that A is a set of alternatives of decision-making A = $\{a_1, a_2, ..., a_m\}$, V is a set of decision matrices V = $\{v_1, v_2, ..., v_n\}$, the attribute of the scheme a_i is X_{ij}(i = 1,2, ..., m ; j = 1, 2, ..., n), then the matrix $X = (x_{ij})_{m \times n}$ is the decision matrix of the set A of the scheme.

2.2.2 Evaluation index matrix standardized treatment

In the standardization of qualitative indicators and quantitative indicators to be used when the different treatment methods.

Quantitative function of the benefit index V_j:

$$x'_{ij} = \frac{x_{ij}}{\max\limits_{1 \le i \le m} x_{ij}} \quad (3)$$

Quantitative function of cost index V_j:

$$x'_{ij} = \frac{\max\limits_{1 \le i \le m} x_{ij} + \min\limits_{1 \le i \le m} x_{ij} - x_{ij}}{\max\limits_{1 \le i \le m} x_{ij}} \quad (4)$$

Quantitative function of qualitative index V_j:

$$x'_{ij} = 1 - \frac{|q_{ij} - x_{ij}|}{\max |q_{ij} - \min\limits_{1 \le i \le m} x_{ij}, \max\limits_{1 \le i \le m} x_{ij} - q_{ij}|} \quad (5)$$

2.2.3 Gray correlation coefficient of the program

The gray correlation coefficient of the scheme is based on the relevance of the evaluation scheme index vector and the relative optimal index vector as the criterion of the decision-making scheme, which is derived from the gray relational decision theory[8].The gray correlation coefficient is:

$$\xi_{ij} = \frac{\min\limits_i \min\limits_j |x_{0j} - x_{ij}| + \rho \max\limits_i \max\limits_j |x_{0j} - x_{ij}|}{|x_{0j} - x_{ij}| + \rho \max\limits_i \max\limits_j |x_{0j} - x_{ij}|} \quad (6)$$

In the formula, ρ is the resolution coefficient, generally take 0.5.

According to the above analysis, we can see that the gray relational coefficient matrix is

$$R = \begin{vmatrix} \xi_{11} & \xi_{12} & \cdots & \xi_{1n} \\ \xi_{21} & \xi_{22} & \cdots & \xi_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ \xi_{m1} & \xi_{m2} & \cdots & \xi_{mn} \end{vmatrix} \quad (7)$$

2.3 Comprehensive decision-making model

Evaluation index system of n relative to the overall goal of weight vector $W=(w_1, w_2, ..., w_n)$,Then the weighting degree of the relative optimal scheme is related to each other R':

$$R' = RW = (r_1, r_2 ..., r_n) \quad (8)$$

In the formula, $r_i = \sum\limits_j^n r_{ij} w_j, i = 1,2,...,m$.

Therefore,when $\max(r_1, r_2 ..., r_n)$,Scheme for the planning of the optimal solution.

3 Examples of comprehensive decision-makin method validation

3.1 Construction of line network evaluation system

A Case Study of Urban Rail Transit Network Planning. The network planning have three programs, specific data and parties as listed in Table 2.

Table 2. Data of Urban Rail Transit Planning

Index	Program 1	Program 2	Program 3
Line density	0.73	0.71	0.75
Line Passenger Intensity	2.8	2.7	2.6
Convenient links to core cities	8	7	7
Transfer coefficient	1.41	1.39	1.34
Line length	107.93	107.08	117.14
Staging construction rationality	8	7	7
Engineering difficulties or ease of use	7	7	8
Feasibility of project implementation	8	7	7
the adaptability of urban landscape	8	7	7
In line with the overall urban development plan	8	8	7
the adaptation of urban land use planning	8	8	7
Promote social development	8	7	7
Improve the people's living standards	8	7	7

From the technical evaluation, economic evaluation, environmental evaluation, social evaluation, combined with the actual situation of a city network construction evaluation index system, see Figure 1.

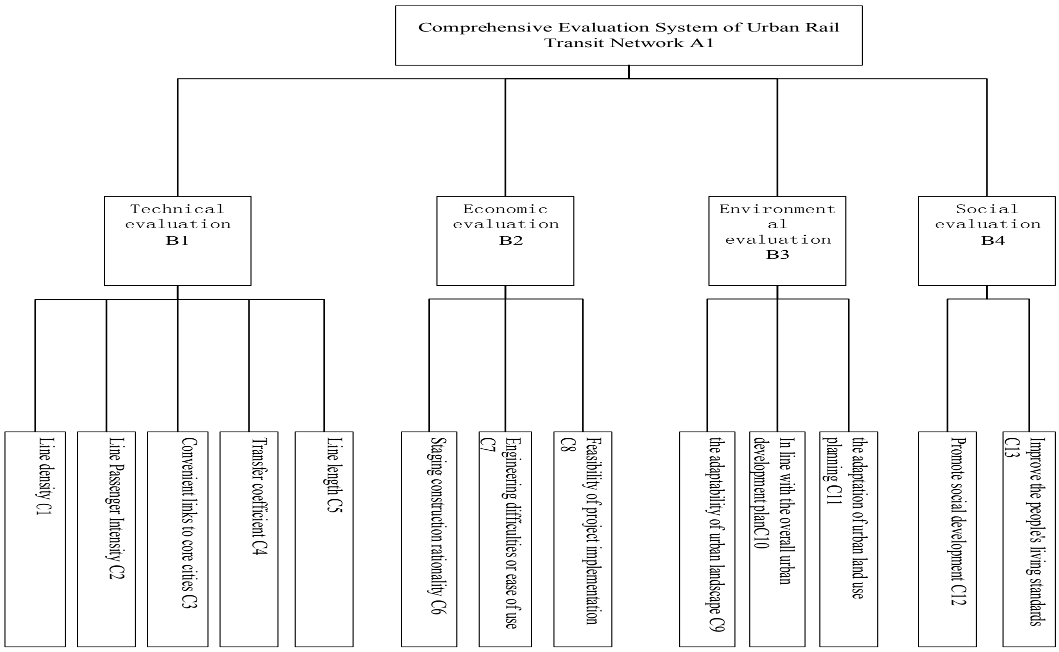

Figure 1. Evaluation Index System of Urban Rail Transit Network

3.2 Determination of the weight of indicators

The AHP method is used to quantify the importance of each evaluation index by using the 1-9 scale method through expert evaluation [10]. The Square root method is used to calculate the weight vector.

Two of each factor to establish judgment matrix and the matrix consistency index as shown in Table3, Table 4 shows the weight of the index system of the evaluation index system.

Table 3. Pairwise Judgment Matrix and Matrix Consistency Index

Calculate the content	A(B1,B2,B3,B4)	B1(C1,C2,C3,C4,C5)	B2(C6,C7,C8)	B3(C9,C10,C11)	B4(C12,C13)
Judgment matrix	1 4 3 5 1/4 1 1/3 1 1/3 3 1 2 1/5 1 1/2 1	1 1/2 4 3 3 2 1 7 5 5 1/4 1/7 1 1/2 1/3 1/3 1/5 2 1 1 1/3 1/5 3 1 1	1 1/5 1/3 5 1 3 3 1/3 1	1 1/3 1/3 3 1 1 3 1 1	1 1/3 3 1
The geometric average	0.549 0.106 0.236 0.109	0.263 0.475 0.055 0.090 0.110	0.105 0.637 0.258	0.143 0.429 0.429	0.250 0.750
Maximum eigenvalue	4.058	5.073	3.039	3	2
Relative consistency index	0.019	0.018	0.0191	0	0
Consistency indicator	0.021<0.1	0.016<0.1	0.033<0.1	0<0.1	0<0.1

Table 4. Urban index system single layer relative weight

Index system stratification		Single layer weight		
Comprehensive Evaluation System of Urban Rail Transit Network A	Technical evaluation B1	Line density C1	0.549	0.263
		Line Passenger Intensity C2		0.475
		Convenient links to core cities C3		0.055
		Transfer coefficient C4		0.090
		Line length C5		0.110
	Economic evaluation B2	Staging construction rationality C6	0.106	0.105
		Engineering difficulties or ease of use C7		0.637
		Feasibility of project implementation C8	0.236	0.258
	Environmental assessment B3	the adaptability of urban landscape C9	0.236	0.143

		the adaptability of urban landscape C10		0.429
		In line with the overall urban development plan C11		0.429
	Social evaluation B4	Promote social development C12	0.109	0.250
		Improve the people's living standards C13		0.750

The combined weights of the layers are calculated, i.E. W=(0.144,0.261,0.030,0.050,0.060,0.011,0.068,0.0273,0.034,0.101,0.101,0.027,0.0818).

3.3 According to the gray method to give each program indicators and indicators of optimal correlation matrix

3.3.1 Determine the decision matrix

$$X = \begin{vmatrix} 0.73 & 2.8 & 8 & 1.41 & 107.93 & 8 & 7 & 8 & 8 & 8 & 8 & 8 & 8 \\ 0.71 & 2.7 & 7 & 1.39 & 107.08 & 8 & 7 & 7 & 7 & 8 & 8 & 7 & 7 \\ 0.75 & 2.6 & 7 & 1.34 & 117.14 & 7 & 8 & 7 & 7 & 7 & 7 & 7 & 7 \end{vmatrix}$$

3.3.2 After the normalized processing, the comprehensive decision matrix is obtained

$$X' = \begin{vmatrix} 0.97 & 1 & 1 & 0.95 & 0.921 & 0.88 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 0.95 & 0.96 & 0.88 & 0.96 & 0.914 & 0.88 & 1 & 0.88 & 0.88 & 1 & 1 & 0.94 & 0.94 \\ 1 & 0.93 & 0.88 & 1 & 1 & 1 & 0.88 & 0.88 & 0.88 & 0,88 & 0.88 & 0.88 & 0.88 \end{vmatrix}$$

3.3.3 Gray relational judgment matrix R, by the formula (6),

$$R = \begin{vmatrix} 0.67 & 1 & 1 & 0.55 & 0.432 & 0.33 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 0.55 & 0.06 & 0.33 & 0.06 & 0.411 & 0.33 & 1 & 0.33 & 0.33 & 1 & 1 & 0.5 & 0.5 \\ 1 & 0.462 & 0.33 & 1 & 1 & 1 & 0.33 & 0.33 & 0.33 & 0.33 & 0.33 & 0.33 & 0.33 \end{vmatrix}$$ W=(0.144,0.261,0.030,0.050,0.060,0.011,0.068,0.0273,0.034,0.101,0.101,0.027,0.0818).

3.3.4 Integrated decision-making

$R'=W^TR=$（0.855,0.481,0.540）
$maxR'=max(r_1,r_2,r_3)=max(0.885,0.481,0.540)=0.885$.
According to the above operation, we can see that the comprehensive decision value of scheme 1 is obviously larger than that of scheme 2 and scheme 3, so the scheme is optimal;Option 2 is the worst, scenario 3 is second, but there is no obvious superiority compared to scenario 1. Therefore, the city rail transit network planning theory should choose the first program.

4 Conclusion

In this paper, the combination decision-making model of AHP-GRAY,using the Analytic Hierarchy Process to determine the weight of evaluation indicators, taking into account the main and objective factors, the scientific description of the actual problem,Based on the establishment of gray relational decision model, combined with examples, the urban rail transit network planning in the three pre-selection program decision-making, and gives the optimal program.This method provides a simple and convenient method for decision-making of line network scheme.

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