Study on the Evaluation Framework System for Regional Comprehensive Transport Planning

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Abstract

Evaluation is an important technical aspect of the Comprehensive Transport Planning. In this paper, the problems in the comprehensive regional transport planning evaluation system, studied the connotation and the concept of comprehensive transport planning evaluation, based on pre-implementation evaluation, the implementation of the process of evaluation and implementation evaluation, the paper put forward multidimensional evaluation framework system and evaluation index. Introduced an assessment idea based on a combination of the ordered weighted averaging (OWA) operator, evaluated the enforceability and expected results based on levels of AHP-Entropy(Analytic Hierarchy Process), given the right of fuzzy comprehensive evaluation and the gray relational grade and evaluated integrate some instances, provide a reference for regional transport planning. Comprehensive Transportation Planning, a systematic analysis of integrated transport planning situation and existing problems, the proposed use of the ideas and methods of transportation planning and systems engineering, means and framework of integrated transport planning and evaluation system, and comprehensive evaluation of transportation planning program, to establish a comprehensive transportation planning program evaluation index system from the program the user point of view, and for the different hierarchical evaluation by the introduction of combination evaluation method based on OWA operator. Through actual case model validation and analysis, validation built evaluation index system and evaluation methods and greater operability. Effect from the program can be implemented, the program is expected to build a system layer, the use of the degree of importance and qualitative analysis to do further screening evaluation index selection, the evaluation screening methods still exists some uncertainty and human factors, and how to select indicators more objective and reasonable remains to be further studied.

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Keywords: Comprehensive transport planning; Index system; Combinational evaluation; OWA aggregation operators

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1. Introduction

During the "Twelfth Five-Year" period, Transportation in China has entered the new stage of the coordinated development of multi-modal transport, and to build a modern integrated transport system to adapt to the characteristics of China's comprehensive transportation system planning, which caused the extensive attention. As an important stage of the integrated transport planning, evaluation and content optimization and decision feedback provide the basis for an important reference for the design of integrated transport. Evaluation optimizes and perfects the planning program through the feedback, which plays a fundamental role in adaptation between integrated regional transportation system and environment of economic resources, and in promoting the development of coordination between the various ways within the system, and in the traffic network system in line with the law of the distribution of passenger and cargo flow goals.

Abroad on integrated transport planning evaluation has been carried out some research: Hine (2000) proposed British GOMMMS transportation planning and evaluation system method, mainly concern for the environment, the land, and the way the convergence problem; Wu (2006) established the planning objectives and planning the two levels of transportation planning program evaluation in United States, to reflect the degree that transportation project planning program meets the social needs and the possibility of realizing the program, and presented requirements of the transport network reliability evaluation; Wang (2002) integrated transport planning in Japan in order to optimize the overall system and transportation network, so they put forward the accessibility and target indicator. Many domestic scholars also do some research about the single way traffic hub, channel planning evaluation: Zhu and other scholars take the Beijing-Shanghai high-speed rail planning as an example, to build the evaluation indicators system of high-speed rail interfacing to the hub; Some scholar defined the category of evaluation as four aspects (see, e.g. Jia et al., 2009): the play of transport function, economic and social adaptability, environmental constraints and resource integration; other scholars have been carried out some research about reasonable degree evaluation for the overall coordination of the development of an integrated transport system and the different modes of transport division. Transportation planning evaluation method has been explored by a number of scholars, the value function method, AHP; principal component analysis was applied in theory or practice.

To analysis the research about transportation planning evaluation, current domestic and international comprehensive transportation planning evaluation, especially the evaluation that covers the reasonableness of planning workflow, the action ability of the planning, mutual adaptation of traffic goals and regional development objective, and the coordination of internal structure and that the work time covered the whole process of the planning is still in the exploratory stage. Traffic hardware facilities and the technical evaluation of the underlying network is more mature, but systematic and comprehensive evaluation method of integrated transport planning programs still need to be further explored. Establish a scientific, systematic, and comprehensive transportation planning evaluation system for regional characteristics framework has an important role in safeguarding regional integrated transport system.

2. The connotation and framework of the Comprehensive Transportation Planning Evaluation System

Integrated transport planning contains physical and institutional planning, and accomplishes the planning step-by-step according to the progressive hierarchy; the evaluation should be based on objective analysis of connotation as a starting point. Rong (2010) proposed the coordination theory, the goal of integrated transport planning can be summarized as the coordinated development, including the development of coordination between the integrated transport system and the external environment, the various subsystems within the integrated transport system as well as the internal subsystems; Based on complex adaptive systems theory, in the planning implementation stage, there are basic characteristics of system between integrated transportation system and regional environmental dynamic evolution, such as co-evolution, alternately pulling and leading, and feedback controllability; The value stream theory stick to that the smooth flow of value is the basis for the coordination development of integrated transport system, circulation effect is largely affected by the circulation of value , integrated transport planning should focus on the implement of the program . Through theoretical analysis of the integrated transport planning target analysis and evaluation, this paper argues that the contents of the framework of integrated transport planning program evaluation should include two aspects: First, implement evaluation of the planning, including technical, economic,
environmental and other target analysis and evaluation of integrated transport planning; Then, the expected implementation effectiveness of the evaluation, covering transportation, economic and social levels, to assess the scale, structure and layout, as well as economic and social benefits of planning integrated transport system.

**Fig. 1. the connotation and framework of the Comprehensive Transportation Planning Evaluation System**

From the time dimension of evaluation, most of the past evaluations conducted during the program development stages of a planning, in recent years, evaluation after the planning implemented have gradually been carried out, but the evaluation that plays a periodic summary and adjustment function to the implementation process is still blank. This paper argues that the time dimension of integrated transport planning and program evaluation should include three stages: First, pre-evaluation before the implementation of planning scheme is the assessment and discussion part of the planning, and it mainly focus on the reasonableness of the technology and economy, adaptability of environment and resource constraints, as well as the overall coordination of the program; Second, the evaluation during the implementation of the program, is to grasp the progress, investment and efficiency of planning in the implementation of the program, which can be the basis for adjustment in follow-up phase. Third, post evaluation after the implementation of the planning, namely, to assess the economic and social benefits after the completion of the project, the coordination between the program and environment, the rationality of internal structure and other aspects. For the implementation of the Comprehensive Transportation Planning, should be on the basis of coordination and covering the various levels of the evaluation content, targeted to establish evaluation model of a comprehensive regional transportation planning programs in various stages according to the characteristics of the different implementation stages, and systematically grasp the rationality of the integrated transport planning program in a complete timing sequence.

3. Evaluation Index System Design

3.1. Overall design

Maimaitiming (2011) designed the evaluation system, considering the feasibility of implementation and expected effect, is to build a comprehensive regional transportation planning program evaluation index system, and the index system is divided into 4 levels: the target layer, system layer, state layer and the index layer.

The first level is the target layer. The layer integrated to express the overall effectiveness of the program of integrated transport planning, and reflected planning program running state and the whole effect of implementation of the strategy.

The second level is the system layer. Integrated transport planning programs are described from the evaluation of the effect of the program and the feasibility of implementation in this the layer.
The third level is the state layer. The layer formulated the principle of choosing assessment indicators, economy, technology, resources and environment, and system integrity of indicators is selected to build the feasibility of implementation evaluation system of the program; selected integrated transport, economic and social benefits to build the effects evaluation system of the program implementation, and broken down into the size, structure, economy and effectiveness evaluation indicators.

The fourth level is the indicator layer. The layer is the lower and basic design specifications of evaluation index system of integrated transport planning programs.

3.2. Classification evaluation design

Evaluation design based on the theoretical basis of the integrated transport and system analysis framework, the reference to the concept of foreign transportation planning evaluation and indicators building ideas, and should pay attention to reflect the difference between the Department of Transportation Planning Evaluation and project evaluation. The evaluation index is designed to reflect the planning objectives, work procedures, rationality and scientific of planning methods, moreover, the index needs to reflect the economic, social and environmental impact of the project, the evaluation process should embody the idea of sustainable development, and emphasis on coordination of planning projects with existing transportation systems, environmental systems and economic and social system as a whole.

Evaluation index design can divide into the feasibility evaluation of implementation and implement effects evaluation, the feasibility evaluation of implementation index mostly is fuzzy quantitative, implement effects evaluation index mainly is quantitative, and supplemented by qualitative. For the calculation of specific indicators, proximity scale, fitness of technical level, direct benefits and other indicators are more conventional, this article focuses on the definition elaborate of some innovative indicators.

1) The correlation degree of convergence between the mode of transport

\[
R = \frac{1}{3} \left[ \sum_{i,j}^d \left( \frac{r_{ij}}{r_{ji}} \right) + \sum_{i,j}^d \left( \frac{r_{ij}}{r_{ji}} \right) \right] + \frac{1}{4} \left[ \sum_{i,j}^s \left( \frac{r_{ij}}{r_{ji}} \right) + \sum_{i,j}^s \left( \frac{r_{ij}}{r_{ji}} \right) \right]
\]

Where: \( R \)——the degree of fit of the degree of association between the two modes of transport;
\( r_{ij} \)——cross-correlation coefficient between the \( i \)-th and \( j \)-th mode of transport;
\( r'_{ij} \)——international development trends of the \( i \)-mode of transport and the \( j \)-th mode of transport cross-correlation coefficient.

2) Sharing rate ratio of coordination and load balanced

The reasonable contribution rate and the load can maximize the effectiveness of the transportation system, this indicator evaluate the rationality of the transportation mode sharing rate. Its expression is \( \xi_i = S_i / S \). \( \xi_i \)——coordination of \( i \)-th mode of transportation sharing ratio; \( \xi_i \)——the total supply of transport capacity of \( i \)-th mode of transportation; \( S \)——The total supply of transport capacity of the integrated transport system; \( D_i \)——transport demand of \( i \)-th mode of transportation.(\( \xi_i \) is bounded by the following formula:

\[
M_i = S_i / D_i = \xi S / D_i
\]

3) Harmonized Index of regional economic development

This index is defined to reflect the coordination degree of the development of economic and freight, the smaller the index value is, the higher the degree of planning programs and economic coordination is. Represented by the formula:

\[
E = \frac{1}{N} \sum_{i=1}^{N} \left( \frac{T_i - T_{i-1}}{T_{i-1}} \right) / \left( \frac{G_i - G_{i-1}}{G_{i-1}} \right)
\]

\( E \)——Harmonized Index of regional economic development.

The rationality of the planning program coordination and transportation mode sharing rate.
Where: $E$ —— coordinated economic index;

$T_t, T_0$ —— time $t$ and the reference point turnover;

$G_t, G_0$ —— time $t$ and the GDP value of the reference point;

$N$ —— number of points.

**Evaluation index for Comprehensive Transport Planning**

<table>
<thead>
<tr>
<th>Evaluation for Feasibility of planning</th>
<th>Evaluation for Implementation effect of planning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technical feasibility</td>
<td>Benefit of Comprehensive traffic</td>
</tr>
<tr>
<td>Economic efficiency</td>
<td>Benefit of Economic and social</td>
</tr>
<tr>
<td>Good environment</td>
<td></td>
</tr>
<tr>
<td>System Coordination</td>
<td></td>
</tr>
</tbody>
</table>

- Technical reliability
- Rationality of construction sequence
- Rationality of fund scale
- Feasibility of financing plan
- Scale of Environment influence
- Scale of Environment and humane influence
- Coordination of master planning
- Coordination of traffic

<table>
<thead>
<tr>
<th>Gap to perfect scale</th>
<th>Rationality of skill grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coordination of transport</td>
<td>Traffic loading balance</td>
</tr>
<tr>
<td>Coordination of transportation assets and invest</td>
<td>Coordination of regional economics</td>
</tr>
<tr>
<td>Contribution to employment</td>
<td>Time saving benefits</td>
</tr>
<tr>
<td>National economy contribution</td>
<td>Resilience</td>
</tr>
<tr>
<td>Influence to regional equity</td>
<td></td>
</tr>
<tr>
<td>Contribution for resource development</td>
<td></td>
</tr>
</tbody>
</table>

Fig. 2. Comprehensive regional transportation planning program evaluation

4. Comprehensive evaluation model Building

4.1. The idea of evaluation methods

To reasonably evaluate integrated transport planning program, this paper introduces the concept of combination evaluation, the evaluation index system of integrated transport planning structure built in combining with the aforementioned evaluation architecture. The feasibility of implementation evaluation and expected effect evaluation (rule layer) were evaluated by method based on fuzzy comprehensive evaluation of the rights defined by level entropy and gray relevance method respectively, independently evaluated each module, The combination of the evaluation process introduced ideas based on OWA operator, to get an overall rating value of the integrated transport planning program by using the position right to re-weight the right of each part of the system.

4.2. The Feasibility of Implementation Evaluation and Expected Effect Evaluation The fuzzy

Comprehensive evaluation method and the method of gray correlation model are widely introduced, about the combination of AHP and Entropy, model to calculate weight coefficient evaluation factors is carried out as follow:

1) Build Judgment matrix, and use AHP to seek initial target weight coefficient:

$$
\theta_j = (\theta_1, \theta_2, \cdots, \theta_n)^T 
$$

$$
\bar{R} = \left\{ \bar{r}_{ij} \right\}_{n \times n} = \left[ \begin{array}{cccc}
\bar{r}_{11} & \bar{r}_{12} & \cdots & \bar{r}_{1n} \\
\bar{r}_{21} & \bar{r}_{22} & \cdots & \bar{r}_{2n} \\
\vdots & \vdots & \ddots & \vdots \\
\bar{r}_{n1} & \bar{r}_{n2} & \cdots & \bar{r}_{nn}
\end{array} \right] 
$$
2) Determine the consistent treatment of the matrix \( \bar{R} = \{ \bar{r}_{ij} \}_{n \times n} \):

\[
\bar{r}_{ij} = \frac{r_{ij}}{\sum_{i=1}^{n} r_{ij}}
\]

(5)

3) Seek the entropy of index \( E_j \):

\[
E_j = \frac{(\ln n)^3}{\sum_{i=1}^{n} r_{ij} \ln r_{ij}} (0 \leq E_j \leq 1)
\]

(6)

4) The degree of deviation based on entropy-based index \( j \), \( d_j = 1 - E_j \)

5) Calculate the correction factor \( \mu_j \) by the Eq. (2)

6) use \( \mu_j \) to correct initial index weight coefficient \( \theta_j = (\theta_1, \theta_2, \ldots, \theta_n)^T \), then get

\[
\theta'_j = \mu_j \theta_j \left( \sum_{j=1}^{n} \mu_j \right)
\]

(7)

7) Each index coefficient vector \( \omega_j = (\omega_1, \omega_2, \ldots, \omega_n) \), Weight of a combination of values that taken AHP method calculated the initial weight and information entropy corrections, Formula expression:

\[
\omega_j = \rho \theta_j + (1 - \rho) \theta'_j, \quad \rho \text{ usually taken } 0.5
\]

(8)

Using Hierarchy-entropy-based fuzzy comprehensive evaluation method and gray relevant coefficient evaluation to determine the process of regional transportation planning program feasibility of implementation evaluation and expected effect evaluation shown in Fig. 3:

Fig. 3. Evaluation process of feasibility and implementation effect of Comprehensive Transportation Planning

4.3. OWA operator-based combination evaluation

\[
\sum_{j=1}^{n} w_j = 1
\]
1) Basic principle

Yager and Kacprzyk (1997) proposed OWA (Order Weighted Averaging) operator, described multi-attribute variable information between the maximum and minimum operator. Its definition is described as: Set up OWA:

\[ R_n \rightarrow R, \text{ if } OWA_n (a_1, a_2, ..., a_n) = \sum_{j=1}^{n} w_j b_j, \text{ w=(w_1, w_2, ..., w_n) defined as dependent weighting vector with OWA, } w_j \in [0,1]; \sum_{j=1}^{n} w_j = 1, \text{ And } b_j \text{ for the elements of the } j-th \text{ data } (a_1, a_2, ..., a_n), R \text{ is the set of real numbers, function OWA recognized as an ordered weighted average operator.} \]

OWA Operator ordered size of the data \((a_1, a_2, ..., a_n)\) reweighted and reunion, if \(a_j\) was only correlated with the \(j-th\) position of the \(w_j\) combination process, and \(w_j\) was unrelated, then the vector \(w\) was determined as the position weight vector.

2) Evaluation process

1. Preliminary evaluation

Feasibility of implementation evaluation and expected effect evaluation were considered as two different subsystems of the evaluation system, according to the evaluation method described in this article, the respective value of the criteria layer respectively can be carried out.

2. Combined Evaluation

Assuming that among the assessed object, the indicators that need for further comprehensive evaluation of the system layer is \(k\) and evaluation value is the score value, postscript after normalizing was:

\[ U = (U_{ij})_{k \times n}, (i=1, 2, ..., k; j=1, 2, ..., n) \]  

\(U_{ij}\) means the value of the \(i-th\) evaluation index of the system layer of the \(j-th\) evaluation object. The combination of these concepts, a combination of evaluation steps is as follows:

Determined the position weight vector \(w=(w_1, w_2, ..., w_n)\)

\[ w_j = \begin{cases} \frac{1-\lambda}{k} + \lambda, & i = 1 \\ \frac{1-\lambda}{k}, & i \neq 1 \end{cases}, \lambda \in [0,1] \]  

Calculated the ordered component: Rearrange the order size of each system layer index \(U_{ij}\) \((i=1, 2..., k)\) of the \(j-th\) object, Set ordered components for \(U_{ij}\) \((i=1, 2..., k)\). Then, calculated the results:

\[ g_j = g(u_{1j}, u_{2j}, ..., u_{kj}) = \sum_{i=1}^{k} w_i u_{ij} \]  

\(g_j\) \((j=1, 2, ..., n)\) is the overall value of \(j-th\) object, Rearranging the size order of \(g_j\) \((j=1, 2, ..., n)\), then the ultimate combination of evaluation results can be carried out. Thus OWA operator build up the system layer evaluation process, get the overall layer evaluation value (Comprehensive evaluation value of the integrated transportation planning program).
5. Evaluations of Case Studies

According to the aforementioned, this part built the evaluation model and selected the integrated transport planning program of the western province to be evaluated, the evaluation result of which was shown in Table 1. From the results analyzed, the comprehensive evaluation value of the recent planning scheme of the integrated transportation system in the region is 0.78, equivalent of the "General" level in the evaluation rank, while the evaluation value of the medium-term planning is 0.88, at a relatively high level. From the evaluation value change of the planning program in the entire planning evaluation period of view, the overall value shows a positive upward trend and the growth is relatively stable, this development law embodies the implementation effect of the transportation infrastructure construction project has the characteristics of hysteresis.

Table 1. The evaluation results of a province’s integrated transportation system planning program

<table>
<thead>
<tr>
<th>Evaluation components</th>
<th>Evaluation manifestations</th>
<th>Recent planning</th>
<th>Medium-term planning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evaluation for the feasibility of the integrated</td>
<td>The evaluation results</td>
<td>81.36</td>
<td>92.10</td>
</tr>
<tr>
<td>transportation planning program</td>
<td>The proportion of the membership</td>
<td>Better(53%)</td>
<td>good (65%)</td>
</tr>
<tr>
<td>Standardization</td>
<td></td>
<td>0.8137</td>
<td>0.9230</td>
</tr>
<tr>
<td>Evaluation for the expected effect of the integrated</td>
<td>The evaluation results</td>
<td>0.7492</td>
<td>0.8465</td>
</tr>
<tr>
<td>transportation planning program</td>
<td>Standardization</td>
<td>0.7492</td>
<td>0.8465</td>
</tr>
<tr>
<td>Evaluation for the integrated transport planning program</td>
<td>The evaluation results</td>
<td>0.7832</td>
<td>0.8805</td>
</tr>
<tr>
<td>based on OWA operator</td>
<td>Comment</td>
<td>General</td>
<td>good</td>
</tr>
</tbody>
</table>

Note: The evaluation rank is divided into poor, worse, general, good and better five degrees, and the corresponding evaluation value nodes are 0.6, 0.7, 0.8, and 0.9.

6. Conclusion

As the integrated transport planning is a systematic discipline, this paper proposed the ideas and methods of combining transportation planning with systems engineering, and explored the meaning and evaluation framework for the integrated transport planning system by analysing the situation and existing problems of the integrated transport planning, then conducted the comprehensive evaluation for different integrated transportation system planning programs, further established the evaluation index system of the integrated transportation planning program from the program user point of view, finally introduced the combination evaluation method based on OWA operator according to different situations of the hierarchical evaluation. Through the model validation and analysis of actual case, this paper verified the rationality and strong operability of the constructed evaluation index system and method.

Overall, this paper constructed system layer from the feasibility and the expected implementation effect these two aspects about the integrated transportation planning program, and applied the importance degree and qualitative analysis to further screen those selected evaluation indexes. However, the screening method of evaluation indexes remains some uncertainty and human factors, and how to select an evaluation index more objectively and reasonability remains to be further studied.

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