Assessment and Analysis about the Impact of Heavy Haul Transportation to Railway Sustainable Development

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Summary: Establishing evaluation index system of heavy-haul transportation on railway sustainable development from the aspect of social economy, transport capacity and economic benefit, energy resources occupied, environmental protection, calculating with multilevel fuzzy comprehensive evaluation method which combine AHP with fuzzy recognition theory, quantitatively evaluate the effect of China railway heavy-haul transportation on railway sustainable development. Calculating and compared with a certain heavy haul railway and national railway freight in 2010 as example, the results showed that the promoting effect on sustainable development of heavy-haul transportation represented by heavy-haul railway outclass that of national railway average level, which reflects that the heavy haul railway makes great contribution to china's economic development and railway sustainable development in aspect of coal transportation.

Compared with other transportation modes, railway has the advantages of low energy consumption, less environment pollution, less resource occupied, so it is considered as green transportation[1], which has obtained the universal approval[2,3]. Heavy haul railway has attracted a widely attention by the railway all over the world because of large transport capacity, high efficiency and low transportation cost, which becomes one of the most important directions of railway sustainable development. Since the 1980s, Chinese railway considered studies on different kinds of heavy haul train transport mode as method by using experience of other countries for reference to turn the passive state of shortage and delay of transport capacity. With more than 20 years' effort, the heavy haul technical level of Chinese railway improved significantly and is among the advanced ranks in this field in the world.

This article establishes an evaluation index system of railway sustainable development, and take a certain heavy haul railway in china as an example to compare with the Chinese ordinary railway transport, in order to study the effect of heavy haul railway on railway sustainable development.

Keywords: heavy-haul; sustainable development; evaluation

1. EVALUATION INDEX SYSTEM
The basic starting point and basic goal of the study on the evaluation index system of railway sustainable development is: analyzing the integrated development situation and trend of railway, society, economic, energy, resources and environment, establishing the framework of sustainable development index system and comprehensive evaluation model which can be used to explain, evaluate, monitor the level of railway sustainable development and provide decision support, thus to evaluate the sustainable development situation of china's railway industry.

The main impact factors can be gotten through analyzing, identifying and selecting by expert judging method and principal component analysis method, and the evaluation
index system is established. The index set is shown in Fig. 1.

2. EVALUATION METHOD

The evaluation of railway sustainable development is a multi-index comprehensive evaluation. The evaluation process transforms the statistical indexes of different dimensions and represent different respects of the evaluated objects to dimensionless relative evaluation value, and obtains a whole evaluation integrating these evaluation values. Researching on the evaluation index system of railway sustainable development needs to start from the railway industry and the characteristic of basic data, select proper evaluation method according to the evaluation goal.

2.1 Method of nondimensionalization

The purpose of nondimensionalizing the indexes is to eliminate the incommensurability because of different measurement units. The evaluation indexes of railway sustainable development can be divided into benefit type (the more the better) and cost type (the less the better). Considering the characteristics of every index and the analysis aim, the following nondimensionalizing methods can be adopted.

- **Standard function of nondimensionalizing benefit indexes:**

\[ y_j = \frac{x_j - \min_{i} x_i}{\max_{i} x_i - \min_{i} x_i} \]

- **Standard function of nondimensionalizing cost indexes:**

\[ y'_j = \frac{\max_{i} x_i - x_j}{\max_{i} x_i - \min_{i} x_i} \]

### Table I - Index Set

<table>
<thead>
<tr>
<th>Index Layer</th>
<th>Index Description</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Top layer</strong></td>
<td>The contribution of railway sustainable development</td>
<td></td>
</tr>
<tr>
<td><strong>Middle layer</strong></td>
<td>1. The contribution of railway sustainable development (Mineral coal consumption per turnover volume)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2. The contribution of railway sustainable development (Coal consumption per turnover volume)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. The contribution of railway sustainable development (Oil consumption per turnover volume)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4. The contribution of railway sustainable development (Natural gas consumption per turnover volume)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5. The contribution of railway sustainable development (Water consumption per turnover volume)</td>
<td></td>
</tr>
</tbody>
</table>

### Figure 1: The evaluation index system of railway sustainable development
2.2 The method of determining the weight of indexes

In the process of multi-index comprehensive evaluation, making certain of index weights is a most important and basic work. The index weight values directly affect the result of comprehensive evaluation. So far there are a lot of methods of determining index weights. They can basically be attributed to two major categories, one is the method of objective weighting. Evaluators give a human evaluation on the importance of the indexes based on objective environment. The other is the method of subjective weighting. The weights can be calculated from different aspects according to the information provided by the changes of indicator data. The two methods have their own advantages and disadvantages. The method of subjective weighting can take the actual situation into account, so it can make the index weights have more practical significances. However, the method brings person subjective arbitrariness inevitably. The method of objective weighting pays too much attention to the characteristics of the index values. Although it avoids the consequences of subjective judgment, but the determining of weights doesn’t fully consider the relative importance of the indexes, also it overlooks the evaluator’s subjective information. So in applications, it often need to integrate the objective and subjective methods.

The Analytic Hierarchy Process (AHP)\(^{[4,5]}\) is not only a simple method to analyze non-quantitative event quantificationally, but also a effective method to describe people’s subjective judgment objectively. So this article adopts AHP to determine the weight of indexes.

2.3 Comprehensive evaluation method

According to the characteristics of evaluation of railway sustainable development, multilevel fuzzy comprehensive evaluation method which combines AHP with fuzzy recognition theory can be adopted to evaluate comprehensively, and this method has advantages as follows: Using AHP which is more objectively to determine index weights to make up the defect of fuzzy comprehensive evaluation whose subjectivity is strong; During the comprehensive evaluation, every qualitative index can be quantified by expert consultation and statistical theory of fuzzy set; The method can not only compare the sustainable development degree of different periods longitudinally, but also can compare that of different sections transversely.

The basic thinking of multilevel fuzzy comprehensive evaluation on railway sustainable development is: the sustainable development status is divided into four —— strong, basic, weak and unsustainable; by recognizing and calculating the relative degree of membership that every evaluation index belongs to the four statuses, the relative status (level) characteristic value is calculated, thus which status the railway sustainable development belongs to can be recognized. The detailed evaluation thought is as followed:

(1) Establish the evaluation index system, and nondimensionalize indexes

A mxn orders matrix of original data with n samples and m evaluation indexes, and a mxc orders matrix of standard value with c grades are established. Using the former nondimensionalizing method, the matrix R=(R\(_{ij}\))\(_{mxm}\) of relative membership degree (dimensionless) of every evaluation index and S=(S\(_{i}\))\(_{mc}\) of standard relative membership degree can be obtained.

(2) Calculate the weight of m evaluation indexes by AHP.

\[ W=(W_1, W_2, \ldots, W_m) \quad \sum_{i=1}^{m} W_i = 1 \]

(3) Calculate relative subordinated vector of different evaluation objects (or years) \(j\) on level \(h\).

\[ V_j = (V_{1j}, V_{2j}, \ldots, V_{cj}) \]

(4) Calculate the level characteristic value of railway sustainable development degree of evaluation object (or year) \(j\) by level characteristic value formula.

\[ H_j = \begin{pmatrix} 1, 2, \ldots, c \end{pmatrix} \cdot (V_{1j}, V_{2j}, \ldots, V_{cj})^T \]

(5) Analysis of results

The calculation results are different level characteristic values (the value can be decimals ), and they can be corresponded respectively to the meaning as follows.

Level characteristic value 1: unsustainable railway development. At this level the railway has such characteristics as backward infrastructure, bad service, poor contribution to social economy, low utilization rate of power and resource, no attention to environmental protection.

Level characteristic value 2: weak railway sustainable development.

Level characteristic value 3: basic railway sustainable development.

Level characteristic value 4: strong railway sustainable development. At this level the railway infrastructure and service have reached a high level, and it is suitable to social economy development. What’s more, the railway management and control has reached a high level, and the utilization rate of power and resource is high, and the railway development is coordinated to environment.

3. THE IMPACT ASSESSMENT OF HEAVY HAUL TO RAILWAY SUSTAINABLE DEVELOPMENT

By above evaluation method, a comparative evaluation is calculated on the impact of a heavy haul railway and the national railway freight to Chinese railway sustainable development.
development in 2010. The whole length of the heavy haul railway is about 650 km, the yearly transportation is about 300 to 400 million tons, and the train traction weight up to 20,000 tons.

3.1 The collection and calculation of original data

For statistical data is difficult to get completely, some values of indexes listed in fig.1 can’t be gotten. So we selects indexes to construct the evaluation system of are selected to construct the evaluation system about the Impact of heavy haul transportation to railway sustainable development. The original values of heavy haul are transferred to relative numbers divided by the values of national railway. The relative values are listed in Table 1.

The data are undimensionalized, and the influence degree of the heavy haul railway and the national railway freight on the sustainable development in 2010 are calculated using the multi-level fuzzy evaluation method, as shown in Table 2.

3.2 Analysis of the evaluation results

From the above calculation results we know that the sustainable development value of this heavy haul railway is 3.04, belonging to basic sustainable development. That of the national railway is 1.865, weak sustainable development. The role of heavy haul railway in promoting sustainable development is much higher than the ordinary national railway.

### Table 1: The relevant data about the heavy haul railway and national railway in 2010

<table>
<thead>
<tr>
<th>Index name</th>
<th>Unit</th>
<th>The heavy haul railway</th>
<th>National Railway</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investment on the fixed-asset per kilometer</td>
<td>Ten thousand Yuan/km</td>
<td>2.850</td>
<td>1</td>
</tr>
<tr>
<td>Contribution of the turnover to GDP per kilometer</td>
<td>Ten thousand Yuan/km</td>
<td>12.692</td>
<td>1</td>
</tr>
<tr>
<td>Index of providing employment per kilometer</td>
<td>Number/km</td>
<td>2.850</td>
<td>1</td>
</tr>
<tr>
<td>Boost to other industries per kilometer</td>
<td>Ten thousand Yuan/km</td>
<td>2.850</td>
<td>1</td>
</tr>
<tr>
<td>Density of freight transport</td>
<td>Hundred million t/km</td>
<td>13.000</td>
<td>1</td>
</tr>
<tr>
<td>Technical speed of freight train</td>
<td>km/h</td>
<td>1.077</td>
<td>1</td>
</tr>
<tr>
<td>Travel Speed of freight train</td>
<td>km/h</td>
<td>1.437</td>
<td>1</td>
</tr>
<tr>
<td>Income rate of freight transport per unit turnover</td>
<td>Yuan/10 thousand t/km</td>
<td>1.634</td>
<td>1</td>
</tr>
<tr>
<td>Occupation of energy and resource, situation of environmental protection</td>
<td>kW/h/10 thousand t/km</td>
<td>0.560</td>
<td>1</td>
</tr>
</tbody>
</table>

### Table 2: Impact comparison of the heavy haul railway and the national railway freight on Chinese railway sustainable development in 2010

<table>
<thead>
<tr>
<th>Index name</th>
<th>The weight</th>
<th>The heavy haul railway</th>
<th>The national railway</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contribution to socio-economy</td>
<td>0.25</td>
<td>3.164</td>
<td>1.887</td>
</tr>
<tr>
<td>Transport capacity and economic efficiency</td>
<td>0.50</td>
<td>2.950</td>
<td>1.778</td>
</tr>
<tr>
<td>Occupation of energy and resource, situation of environmental protection</td>
<td>0.25</td>
<td>3.095</td>
<td>2.016</td>
</tr>
<tr>
<td>Evaluation value of the railway sustainable development</td>
<td>3.040</td>
<td>1.865</td>
<td></td>
</tr>
</tbody>
</table>
In three sub-goals, the heavy haul railway is at the level of sustainable development. The national railway is at the level of weak sustainable development. The evaluation value of ordinary national railway on the third sub-goal 'Occupation of energy and resource, situation of environmental protection' is higher than the other two sub-goals. It explains the advantages of railway transportation mode in the sustainable development of energy saving and environmental protection, but the value of 'Contribution to socio-economy' is low, especially the evaluation value of 'Transport capacity and economic efficiency' is lowest. Those reflect the heavy haul railway made a great contribution to sustainable development of China's economic development and the railway on freight transportation.

4. CONCLUSIONS AND RECOMMENDATIONS

(1) Constructing heavy transport corridors
The development of heavy haul transport is an important method to increase railway transportation capacity and achieves sustainable development. In building new lines, advanced technological methods should be used to develop the heavy haul transport vigorously, and construct new heavy haul transport corridors, thus to increase the railway freight capacity, and further enhance the contribution of railway transportation to the development of national economy.

(2) Using transport organization mode of heavy haul train
The transport organization mode of heavy haul determines the efficiency and benefit of heavy haul transport directly. Heavy transport corridors can achieve the organizational model that collection and distribution integration by learning the successful experience of organization of cargo flow, traffic organization, trains running organization and so on from the heavy haul railway above mentioned, to maximize the operating efficiency of heavy haul transport as a whole and maximize the social benefits.

(3) Relaxing the controls on the rail freight tariffs
The low level of rail freight tariffs has affected the development of railway industry and the country's infrastructure. This heavy haul railway above mentioned performed special tariffs and have achieved a better economic benefit. The government should relax controlling on railway cargo tariffs appropriately, and implement market-oriented operation localized within certain periods, certain areas, certain goods categories to format equilibrium price of rail freight services market, to improve rail freight revenues and promote the sustainable development of railway.

REFERENCES
