
Ting Pan, Yanfei Zhang, Yongqiang Wang

Abstract—In recent years, intensive road passenger line has become a part of the construction of various cities. In this paper, in order to carry out a detailed evaluation of the operation of the line intensive transformation. Therefore, the post-evaluation system was established in this paper, including 13 indicators such as common bus network density, average travel time and traffic punctuality rate. The scoring method was used to determine the weight of the evaluation index. The eunecis and the extension matter-element method were used to establish the evaluation model. Thus, the already intensive road passenger line was post-evaluated by Zibo City at the end of 2015.

Index Terms—Road passenger line, Intensive transformation, Post Evaluation, Extension Matter Element Method.

I. INTRODUCTION

Traffic authorities and business lines of the enterprises did not timely after the transformation of passenger lines and the operation of the results of the summary and evaluation. Based on the extended matter-element method, the pull-off method is used to determine the weight of the evaluation index, a set of 13 indicators of the evaluation system is composed of three criteria for the evaluation of the road passenger line intensive reform of the post-evaluation system was established.

II. EXTENSION MATTER-ELEMENT METHOD

The extension system is a new discipline founded by Chinese scholar Cai Wen. Its system mainly includes three parts: extension theory, extension development and application of extension theory, extension method and extension engineering method [1] [2]. Extension theory as the basis of the latter two, the latter two as a practical application of the tool [3]. And the material-element extension method is based on the extension of the theory formed by the method, the specific concept is as follows.

A. Matter-element concept

Matter-element is used to describe the basic abbreviation of things, the expression is:

\[ R(U, A, X) \]  

Where, \( U \) is the object (evaluation object), \( A \) is the feature name (index name), \( X \) is the specific value of the object (index value), \( U \), \( A \) and \( X \) are called the three elements of the matter element \( R \), \( A \) and \( X \) is a feature of a binary (called a matter). There is a close relationship between the three elements of matter-element, and there is a one-to-one relationship for the same object \( U \), \( A \) and \( X \), which can be expressed by \( X = U(A) \ (A, A_1, \ldots, A_n) \) and the corresponding magnitude \( X = (X_1, X_2, \ldots, X_n) \), the matter element can usually be expressed as the following matrix form:

\[
R = \begin{pmatrix}
U & A_1 & X_1 \\
A_2 & X_2 \\
\vdots & \vdots \\
A_n & X_n \\
\end{pmatrix} = \begin{pmatrix}
R_1 \\
R_2 \\
\vdots \\
R_n \\
\end{pmatrix}
\]  

(2)

In this formula, \( R \) is the matter-element to be evaluated, \( U \) is the grade of the thing to be studied, \( A \) is the name of the item to be evaluated at level \( U \), and all the relevant feature names are listed. \( X \) represents the value of \( A \) at level \( U \), which can be either a range of values (classical and thresholding), or a specific value (matrix of matter to be evaluated).

B. Classic domain matter element

For the material element \( S_{ij} \) and \( U_{oi} \) that the division of the \( j \) evaluation level. If the respective characteristics of \( A \) corresponding \( X_{oi} \) all with the interval to represent the classic domain matter element can be determined, \( X_{oi} \) is the classic domain:

\[
R_{ij} = R(U_{oi}, A, X_{oi}) = \begin{pmatrix}
U_{oi} & A_i & X_{oi} \\
A_2 & X_{oi} \\
\vdots & \vdots \\
A_n & X_{oi} \\
\end{pmatrix} = \begin{pmatrix}
A_i \\
A_2 \\
\vdots \\
A_n \\
\end{pmatrix} \begin{pmatrix}
m_{oi}^{min} & m_{oi}^{max}
\end{pmatrix}
\]  

(3)

Where, \( i = (1,2,\ldots,n) \), \( j \) is the rating of the main body, the evaluation system established in this paper has five levels (ie, excellent, better, qualified, poor, very poor), so \( j = 1,2,3,4,5 \), \( m_{oi}^{min} \) is the lower limit of \( X_{oi} \), \( M_{oi}^{max} \) is the upper limit of \( X_{oi} \).

C. Section domain matter element

\[
R_{ij} = (U_{ij}, A, X_{ij}) = \begin{pmatrix}
U_{ij} & A_i & X_{ij} \\
A_2 & X_{ij} \\
\vdots & \vdots \\
A_n & X_{ij} \\
\end{pmatrix} = R_{ij} = \begin{pmatrix}
A_i \\
A_2 \\
\vdots \\
A_n \\
\end{pmatrix} \begin{pmatrix}
m_{ij}^{min} & m_{ij}^{max}
\end{pmatrix}
\]  

(4)

Where, \( U_P \) is the whole of the evaluation level, and \( X_{P}^i \) is the range of values taken by \( P \) for \( A_i \) (that is, the node of \( P \)). \( m_{P}^{\text{min}} \) is the lower limit of \( X_{P}^{\text{min}} \) and \( M_{P}^{\text{max}} \) is the upper limit of \( X_{P}^{\text{max}} \), of course, the classic domain \( X_{P}^{\text{min}} \) belongs to the section \( X_{P}^{\text{max}} \).

D. To be assessed matter element

For the specific line intensive management \( U \) to be evaluated, according to the data of the collated and processed, the specific value \( X_i \) of each corresponding index can be obtained, and the matter element to be evaluated based on the object to be evaluated can be established:

\[
R = \left[ \begin{array}{ccc}
U & A_1 & X_1 \\
A_2 & X_2 \\
& L & L \\
A_n & X_n \\
\end{array} \right]
\]  

E. Associated functions

1) Distance. This is different from the generalized distance, rather than the distance between two points, the range here is the distance from the domain of the domain, the classic domain, and so on. Assuming that \( x \) is any point on the real field \((-\infty, +\infty)\), \( X_0 = (a, b) \) is any interval on the real field, the distance is:

\[
\rho(x, X_0) = \frac{|x - a + b|}{2} - \frac{(b - a)}{2}
\]  

The distance from point \( x \) to interval \( X_0 \). In the specific application, the paper needs to establish the relationship between the two distance, one is the actual value of the index to be evaluated and the corresponding classic domain distance, as follows:

\[
\rho(X_i, X_{\ast}) = \left| \frac{X_i - m_{\ast} + M_{\ast}}{2} - \frac{M_{\ast} - m_{\ast}}{2} \right|
\]  

One is the actual value of the index to be evaluated and the distance from the domain is used to indicate the distance between the index to be evaluated and the level field, as follows:

\[
\rho(X_i, X_{\ast}) = \left| \frac{X_i - m_{\ast} + M_{\ast}}{2} - \frac{M_{\ast} - m_{\ast}}{2} \right|
\]  

2) Associative function

\[
K(X_i) = \left\{ \begin{array}{ccc}
-\frac{\rho(x, X_{\ast})}{|X_{\ast}|}, & x_i \in X_{\ast} \\
\frac{\rho(x, X_{\ast})}{|X_{\ast}|}, & x_i \not\in X_{\ast}
\end{array} \right.
\]  

Indicates the degree of compliance between the \( i \) evaluation index \( A_i \) and the \( j \) rating level of the item to be evaluated. When \( K_i(X_i) \geq 0 \), \( X_i \) is \( X_{\ast} \); \( X_i \) is larger, indicating that \( X_i \) has the property of \( X_{\ast} \), the more usually the range of \( \max K_i(X_i) \), the reaction is the membership of the material level, the opposite. \( K_i(X_i) \leq 0 \). \( X_i \) does not belong to \( X_{\ast} \), the smaller the value, \( X_i \) distance away from the distance \( X_{\ast} \).

F. Comprehensive correlation

\[
K_j(U) = \sum_{i=1}^{n} w_i K_i(X_i)
\]  

Where, \( w_i \) is the determined weight of the index. \( K_j(U) \) represents the degree to which \( U \) belongs to \( j \), and it is the maximum, then \( U \) belongs to \( j \). In general, the degree of relevance of the evaluation object can be divided into three cases, the meaning of the table as shown in table 1

<table>
<thead>
<tr>
<th>Correlation calculation</th>
<th>Whether the nature of the evaluation is within this level</th>
<th>Whether the qualification to convert to that level</th>
<th>Result meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>( K_i(U) ) &gt; 0</td>
<td>yes</td>
<td>yes</td>
<td>The larger the value, the larger the degree of membership</td>
</tr>
<tr>
<td>(-1 &lt; K_i(U) &lt; 0 )</td>
<td>no</td>
<td>yes</td>
<td>The larger the value, the larger the likelihood of conversion</td>
</tr>
<tr>
<td>( K_i(U) \leq -1 )</td>
<td>no</td>
<td>no</td>
<td>The smaller the value, the farther away from the level</td>
</tr>
</tbody>
</table>

III. POST-EVALUATION SYSTEM ESTABLISHED

The establishment of the road passenger line intensive reform effect post-evaluation system as shown in figure1

![Flow chart](https://via.placeholder.com/550x338)

All indicators of the classification criteria as shown in table 2. [4] [5]
Table 2 Indicator level classification standard table

<table>
<thead>
<tr>
<th>Index</th>
<th>Indicator range</th>
<th>Evaluation grade</th>
<th>Index</th>
<th>Indicator range</th>
<th>Evaluation grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bus network density C1</td>
<td>2.2-2.5km/km²</td>
<td>I</td>
<td>Driving standard point rate C7</td>
<td>1min</td>
<td>I</td>
</tr>
<tr>
<td></td>
<td>2.5-3km/km²</td>
<td>II</td>
<td></td>
<td>1-3min</td>
<td>II</td>
</tr>
<tr>
<td></td>
<td>3-4km/km²</td>
<td>III</td>
<td></td>
<td>3-5min</td>
<td>III</td>
</tr>
<tr>
<td></td>
<td>1-2km/km²</td>
<td>IV</td>
<td></td>
<td>&gt;5min</td>
<td>IV</td>
</tr>
<tr>
<td>Line non-linear coefficient C2</td>
<td>1.4</td>
<td>I</td>
<td>Peak vehicle full load rate C8</td>
<td>95-100%</td>
<td>I</td>
</tr>
<tr>
<td></td>
<td>&gt;1.4</td>
<td>According to the deviation of the decision</td>
<td></td>
<td>100%-105%</td>
<td>II</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>105%-110%</td>
<td>III</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>&gt;110%,&lt;95%</td>
<td>IV</td>
</tr>
<tr>
<td>Average station distance C3</td>
<td>500-800</td>
<td>I</td>
<td>Transfer factor C9</td>
<td>1.3</td>
<td>I</td>
</tr>
<tr>
<td></td>
<td>300-500</td>
<td>II</td>
<td></td>
<td>1.3-1.4</td>
<td>II</td>
</tr>
<tr>
<td></td>
<td>800-1000</td>
<td>III</td>
<td></td>
<td>1.4-1.5</td>
<td>III</td>
</tr>
<tr>
<td></td>
<td>&gt;1000</td>
<td>IV</td>
<td></td>
<td>&gt;1.5</td>
<td>IV</td>
</tr>
<tr>
<td>500 m station coverage C4</td>
<td>95%</td>
<td>I</td>
<td>Average cost C10</td>
<td>1 Yuan</td>
<td>I</td>
</tr>
<tr>
<td></td>
<td>85%-95%</td>
<td>II</td>
<td></td>
<td>1-1.5 Yuan</td>
<td>II</td>
</tr>
<tr>
<td></td>
<td>75%-85%</td>
<td>III</td>
<td></td>
<td>1.5-2 Yuan</td>
<td>III</td>
</tr>
<tr>
<td></td>
<td>&lt;75%</td>
<td>IV</td>
<td></td>
<td>&gt;2 Yuan</td>
<td>IV</td>
</tr>
<tr>
<td>Average travel time C5</td>
<td>0-20min</td>
<td>I</td>
<td>Bus sharing rate C11</td>
<td>10%</td>
<td>I</td>
</tr>
<tr>
<td></td>
<td>20-30min</td>
<td>II</td>
<td></td>
<td>5%-10%</td>
<td>II</td>
</tr>
<tr>
<td></td>
<td>30-40min</td>
<td>III</td>
<td></td>
<td>3%-5%</td>
<td>III</td>
</tr>
<tr>
<td></td>
<td>&gt;40min</td>
<td>IV</td>
<td></td>
<td>&lt;3%</td>
<td>IV</td>
</tr>
<tr>
<td>Average running speed C6</td>
<td>20km/h</td>
<td>I</td>
<td>Average running speed C6</td>
<td>10-15km/h</td>
<td>III</td>
</tr>
<tr>
<td></td>
<td>15-20km/h</td>
<td>II</td>
<td></td>
<td>&lt;10km/10</td>
<td>IV</td>
</tr>
</tbody>
</table>

A. Weight determination method

The \( n \) evaluation index of the corresponding evaluation of the main body is defined as \( A = (A_1, A_2, \ldots, A_n) \). The initial observation value matrix \( A = (A_1, A_2, \ldots, A_n) \) is constructed, and \( A^*=[A_1^*, A_2^*, \ldots, A_n^*] \) is obtained after the data is dimensionless. Then, the weight coefficient vector corresponding to each evaluation index is \( w_i (i = 1, 2, \ldots, n) \), and the weight vector matrix \( W = [w_1, w_2, \ldots, w_n]^T \) is established accordingly. Finally, the evaluation function of the evaluation object is \( y_i = w_i g(A^*_i) \), if there is \( Y = [y_1, y_2, \ldots, y_n]^T \), then \( Y = A^*W \).

As can be seen from the above equation, since \( A^* \) is the basic data to be known, the calculated value of \( Y \) is determined by the weighting factor. According to the mathematical principle, the matrix \( A^* \) is composed of \( n \) dimensional vector, the value of the vector of the dimensional vector can be understood as the value of the evaluation object, and the “grade scale-up method”, “As far as possible to distinguish between the differences between the evaluation indicators” principle, it is necessary through the weight coefficient \( W \) to achieve the evaluation of the degree of dispersion of the object to maximize the degree of dispersion, that is, the evaluation of the value of the maximum degree of \( Y \) dispersion is required. [6].

In summary, we can use the variance of \( Y \) to describe, through the calculation can be the following formula \( s^2 = \frac{1}{n} \sum_{i=1}^{n} (y_i - \bar{y})^2 = w^T H w \), where \( H = A^T A^* \) is a real symmetric matrix. Therefore, according to the principle of “grade scale-up method”, the planning model of the weight coefficient of the evaluation index can be constructed \( \max s^2 = w^T H w \), and the constraint condition \( w^T w = 1, w > 0 \).

Theorem: If \( W \) take the standard eigenvector corresponding to the maximum eigenvalue \( \lambda_{max} \) of \( H \), then \( \max s^2 = w^T H w \) obtains the maximum value under the constraint condition: \( \max s^2 = w^T H w \)[7].

Therefore, as long as the maximum eigenvalue corresponding to the largest eigenvector of the matrix \( H \) is calculated, and the normalization is carried out, the weight \( W = (w_1, w_2, \ldots, w_n)^T \) of the evaluation index is obtained, \( \sum_{i=1}^{n} w_i = 1 \).

IV. ZIBO CITY 1 BUS POST-EVALUATION

1) Through the collection of Zibo City 1 bus road passenger transport line intensive transformation of the relevant data, and the evaluation of the rating range and the actual value of the non-dimensional processing to be as shown in table 3.
2) The data and weights of all the indicators obtained by grad scale-up method are also shown in table 3.

Table 3 Data weight table

<table>
<thead>
<tr>
<th>Criterion layer</th>
<th>Names of Index</th>
<th>Index value</th>
<th>Weights</th>
</tr>
</thead>
<tbody>
<tr>
<td>Efficiency level</td>
<td>Bus sharing rate</td>
<td>4.7%</td>
<td>0.068</td>
</tr>
<tr>
<td></td>
<td>Bus Satisfaction</td>
<td>83</td>
<td>0.167</td>
</tr>
<tr>
<td></td>
<td>Safety</td>
<td>85</td>
<td>0.413</td>
</tr>
<tr>
<td>Service level</td>
<td>Average freight</td>
<td>1.25 Yuan</td>
<td>0.077</td>
</tr>
<tr>
<td></td>
<td>Vehicle punctuality</td>
<td>2min</td>
<td>0.020</td>
</tr>
<tr>
<td></td>
<td>Average speed of vehicles</td>
<td>19.87</td>
<td>0.010</td>
</tr>
<tr>
<td></td>
<td>Transfer factor</td>
<td>1.25</td>
<td>0.139</td>
</tr>
<tr>
<td></td>
<td>Vehicle full load rate</td>
<td>55%</td>
<td>0.010</td>
</tr>
<tr>
<td></td>
<td>Average travel time</td>
<td>15.6min</td>
<td>0.040</td>
</tr>
<tr>
<td>Facility level</td>
<td>Bus network density</td>
<td>2.2 km/km²</td>
<td>0.034</td>
</tr>
<tr>
<td></td>
<td>Line non-linear coefficient</td>
<td>1.71</td>
<td>0.005</td>
</tr>
<tr>
<td></td>
<td>Average station distance</td>
<td>636 m</td>
<td>0.012</td>
</tr>
<tr>
<td></td>
<td>500 m station coverage</td>
<td>76%</td>
<td>0.021</td>
</tr>
</tbody>
</table>

On the Intensive Effect of Road Passenger Line

\[ \begin{align*}
U &= \begin{bmatrix}
83 & (0, 100) \\
80 & (0, 100) \\
60 & (0, 80) \\
60 & (0, 80) \\
50 & (0, 40) \\
40 & (0, 60) \\
40 & (0, 60) \\
3 & (0, 3) \\
2 & (0, 40) \\
0 & (0, 40)
\end{bmatrix}
\end{align*} \]

5) To determine the objective element matrix to be evaluated: the actual value of each evaluation index is obtained by data collection, collation and calculation. These values are substituted for the domain value of the membership element matrix, and finally the object element \( U \) is obtained. The process is as follows:

6) Calculate the overall relevance as shown in table 4.

Table 4 Comprehensive correlation degree table

<table>
<thead>
<tr>
<th>Grade</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Efficiency level</td>
<td>-0.05</td>
<td>-1.22</td>
<td>-1.36</td>
<td>-1.9</td>
</tr>
<tr>
<td>Service Level</td>
<td>0.29</td>
<td>-0.33</td>
<td>-0.09</td>
<td>-0.58</td>
</tr>
<tr>
<td>Facility level</td>
<td>0.16</td>
<td>0.07</td>
<td>0.07</td>
<td>0.02</td>
</tr>
<tr>
<td>Total degree of correlation</td>
<td>2.2</td>
<td>9.61</td>
<td>1.36</td>
<td>-6.11</td>
</tr>
</tbody>
</table>

Analysis of post-evaluation results: from the overall relevance of the situation: to be evaluated object U in the second level, then Zibo City 1 bus road passenger line intensive transformation effect is better.

V. CONCLUSION

A post-evaluation system suitable for the intensive transformation of the road passenger line is established on the basis of the actual situation of the road passenger line. And the scientific rationality of the post evaluation system is demonstrated through examples. The post evaluation system...
also applies to post-evaluation of the intensive transformation of the road passenger line in other small and medium-sized cities.

REFERENCES


Ting Pan,
She was born on April, 1990 in Shandong province, China. She is a graduate student at Shandong University of Technology, and major in transportation engineering. Her research direction is the education of traffic safety.

Yanfei Zhang,
She was born on November, 1983 in Shandong province, China. She is a teacher at Shandong Transport Vocational College. Her research direction is the vehicle engineering and the research on college-enterprise cooperation brand new technology.

Yongqing Wang,
He was born on September, 1991 in Shandong province, China. He is a Transportation Planning Engineer at Ji’nan Urban Transportation Research Center, and major in transport planning. His research direction is the Urban transport planning.